THE ULTIMATE SPY
Why the real James Bond is a supercomputer

NEW LOOK, NEW IDEAS

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SCIENCE AND TECH
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The amazing story of how it was measured

Gene insight
Why 'junk' DNA isn't useless after all

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How you can get a good night's rest

DISCOVERING
LOST WORLDS

Unlocking the ancient secrets of Britain's submerged landscape

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Q&A
- Will Jupiter ever ignite?
- Is your height determined by your father?
- What governs life span?

DARA O BRIAIN
TV's funniest science presenter talks Einstein and his new BBC series

ON TEST: ULTRA HD TV
Behind the scenes with the world's most detailed display

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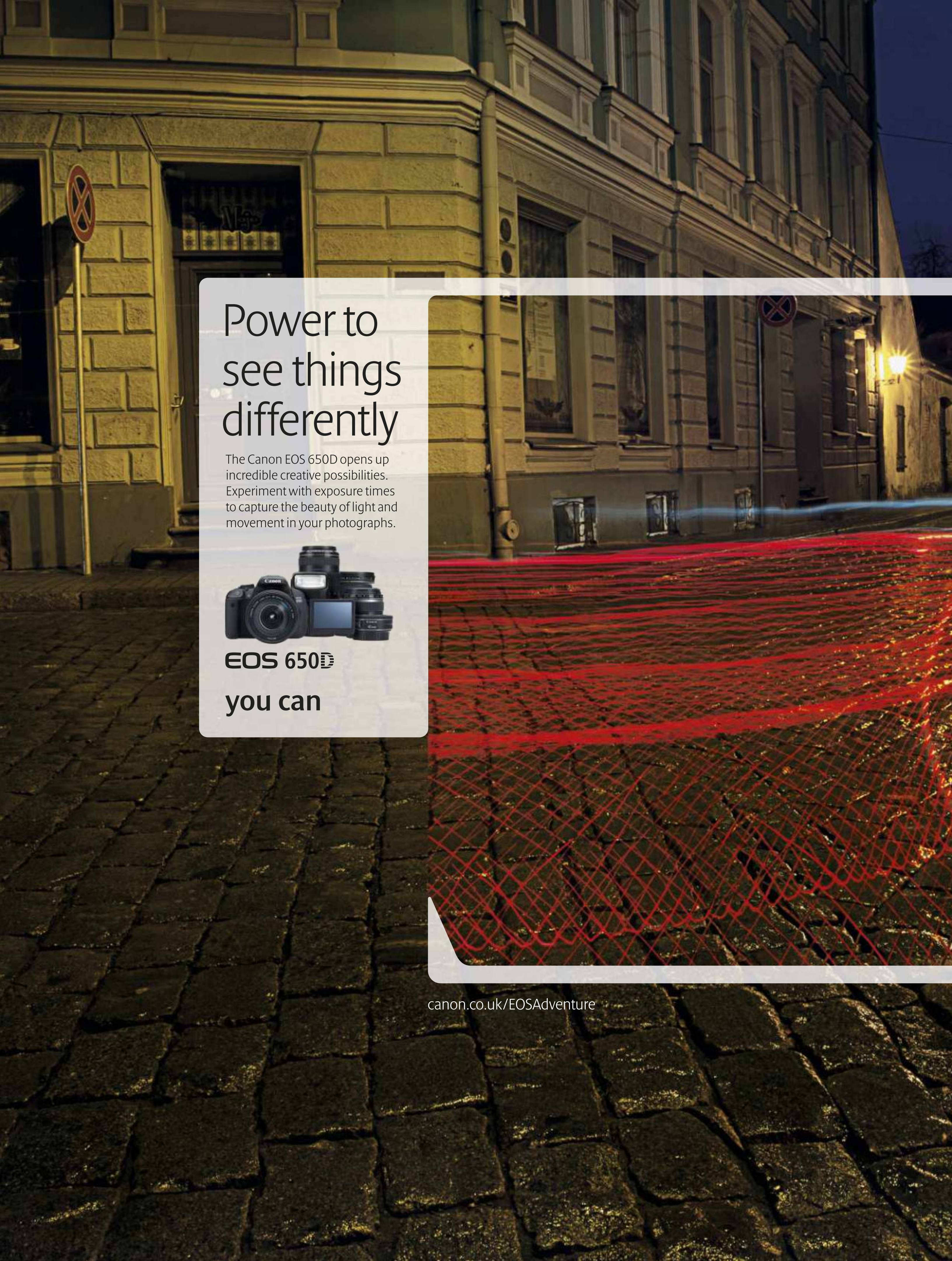

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WELCOME TO FOCUS

LISTEN TO RADIO 4's Shipping Forecast and you'll hear a host of strange names: Dogger, Fisher and German Bight among them. These are regions of sea surrounding the British Isles – Dogger is off the east coast. And it's here that our ancient ancestors lived until 8,000 years ago when a flood washed them away, in the process creating the island we live on. Remarkably, we're beginning to recreate their world, which has been dubbed Doggerland. Scientists have already retrieved man-made objects and mammoth remains, and as archaeologist Mike Pitts reports on p34, we could be on the verge of some truly epic discoveries.

Back in the present, we welcome the return of James Bond to cinema screens with a look at the science of spying. While there may still be dead letter drops and double agents, the main focus of spy organisations like GCHQ appears to be harnessing supercomputers to trawl through data. Security expert Prof Richard J Aldrich investigates on p55.

This month also sees the start of a major new science series on BBC Two. Presented by comedian Dara O Briain, the as-yet untitled show will explore one science topic each week from different angles. We preview the programme on p103, take an in-depth look at one of its topics (the speed of light) on p96 and speak to Dara himself on p52. Enjoy the issue.

Graham

Graham Southorn, Editor

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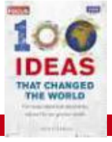

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APPEARING IN THIS ISSUE...

Prof Richard J Aldrich

A professor of international security at the University of Warwick, Richard is the author *GCHQ: The Uncensored Story Of Britain's Most Secret Intelligence Agency*. On p55, he reveals how technology is changing spying.

Heather Couper

The renowned astronomer, author and broadcaster teams up with Nigel Henbest every month to bring you the *Focus* guide to the month's stargazing highlights (see p93). Their annual guide to the night sky, *Stargazing 2013*, is out now.

Dara O Briain

The comedian and *Stargazing Live* presenter returns to our screens with a flagship series for BBC Two. A regular guest on *QI*, he's no stranger to science, having studied maths and theoretical physics at University College Dublin.

Mike Pitts

The editor of the magazine *British Archaeology*, Mike is an active archaeologist himself, having directed digs at both Avebury and Stonehenge. On p34 he reveals the latest discoveries about the lost world off Britain's coast.

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EXISTING SUBSCRIBERS Turn to p30 for an exclusive article on the frontiers of **nuclear physics** by Professor Jim Al-Khalili

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DISCOVERING LOST WORLDS

Science is throwing up some mammoth finds in Britain's sunken landscape

PHOTO: HANS WILDSCHUT, MAGICTORCH, CAMERAPRESS, GETTY, HITANDRUNMEDIA

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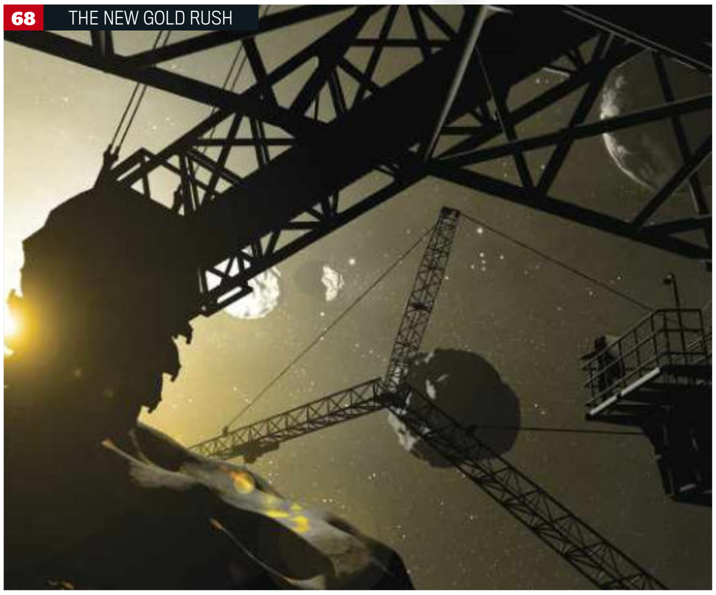

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Awe-inspiring images from the world of science

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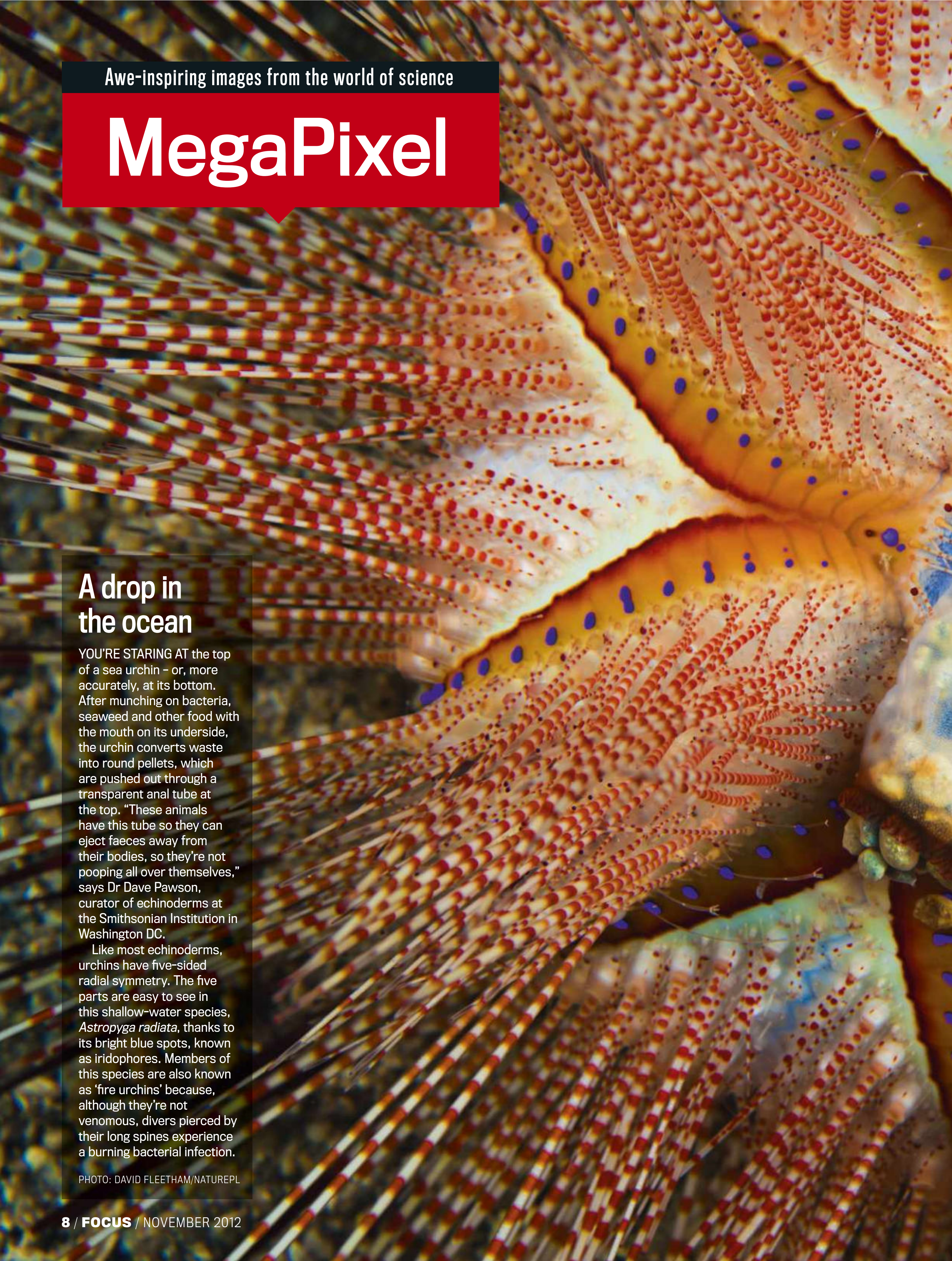
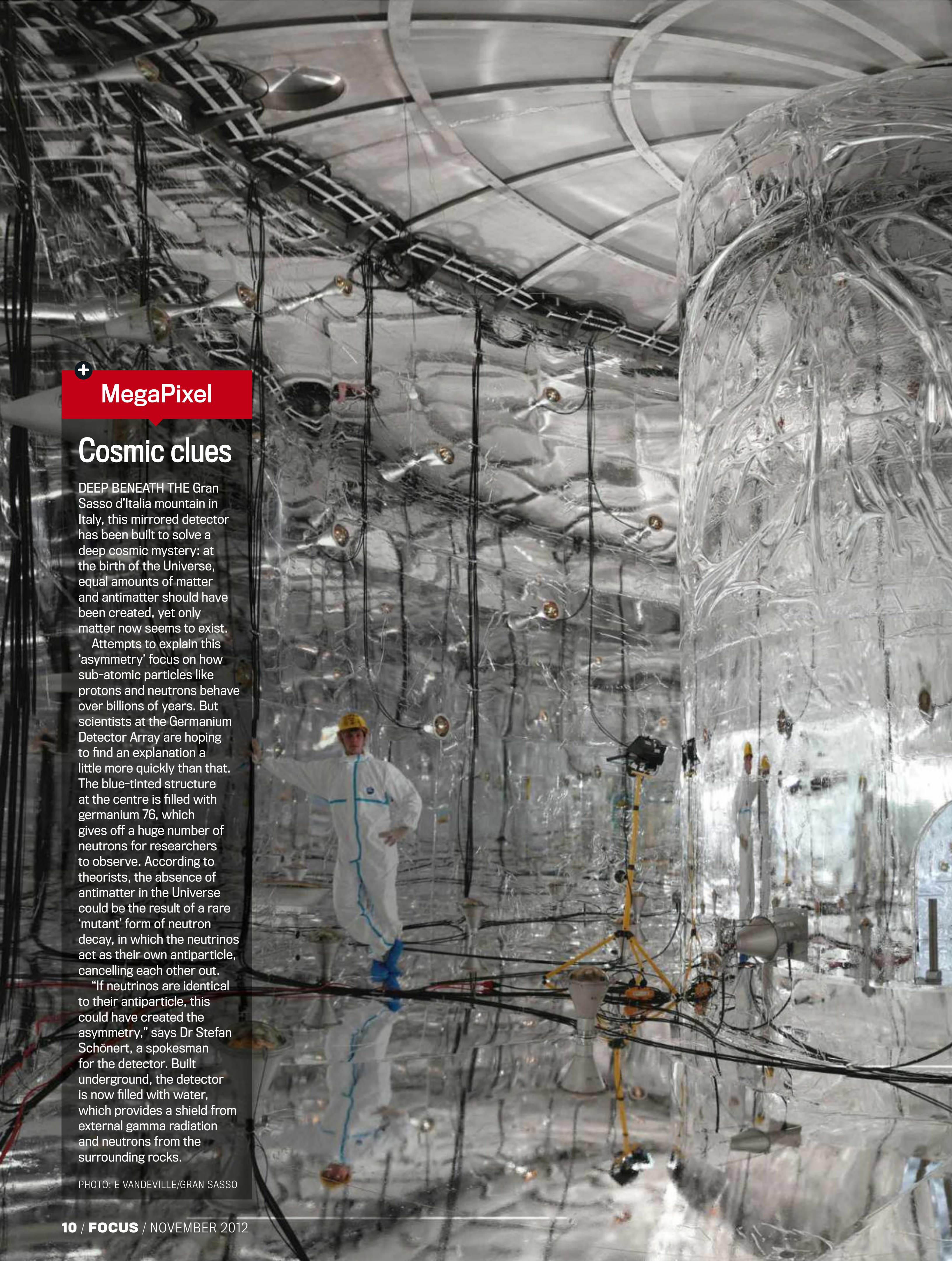


A drop in the ocean

YOU'RE STARING AT the top of a sea urchin – or, more accurately, at its bottom. After munching on bacteria, seaweed and other food with the mouth on its underside, the urchin converts waste into round pellets, which are pushed out through a transparent anal tube at the top. "These animals have this tube so they can eject faeces away from their bodies, so they're not pooping all over themselves," says Dr Dave Pawson, curator of echinoderms at the Smithsonian Institution in Washington DC.

Like most echinoderms, urchins have five-sided radial symmetry. The five parts are easy to see in this shallow-water species, *Astropyga radiata*, thanks to its bright blue spots, known as iridophores. Members of this species are also known as 'fire urchins' because, although they're not venomous, divers pierced by their long spines experience a burning bacterial infection.

PHOTO: DAVID FLEETHAM/NATUREPL



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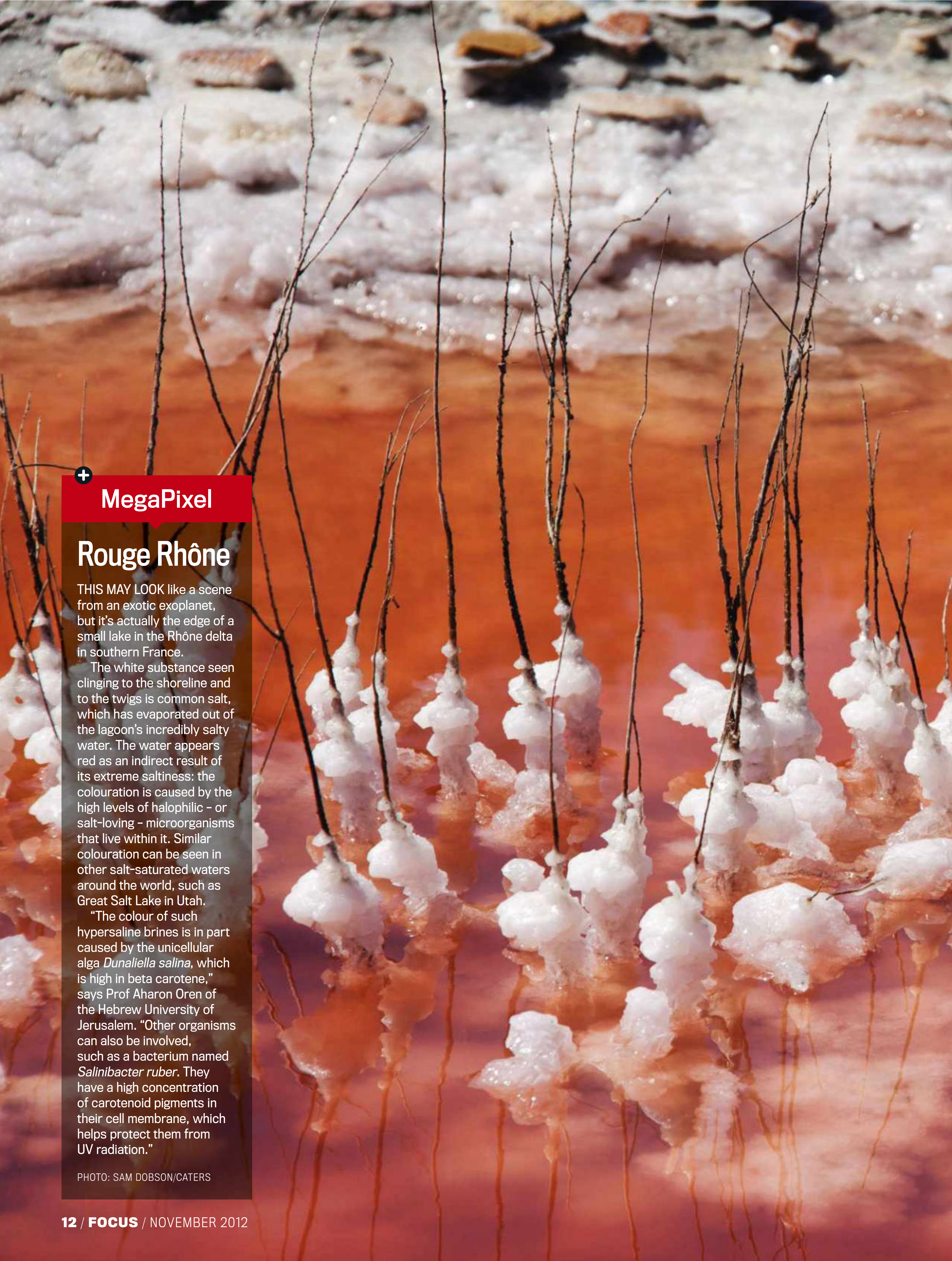
Cosmic clues

DEEP BENEATH THE Gran Sasso d'Italia mountain in Italy, this mirrored detector has been built to solve a deep cosmic mystery: at the birth of the Universe, equal amounts of matter and antimatter should have been created, yet only matter now seems to exist.

Attempts to explain this 'asymmetry' focus on how sub-atomic particles like protons and neutrons behave over billions of years. But scientists at the Germanium Detector Array are hoping to find an explanation a little more quickly than that. The blue-tinted structure at the centre is filled with germanium 76, which gives off a huge number of neutrons for researchers to observe. According to theorists, the absence of antimatter in the Universe could be the result of a rare 'mutant' form of neutron decay, in which the neutrinos act as their own antiparticle, cancelling each other out.

"If neutrinos are identical to their antiparticle, this could have created the asymmetry," says Dr Stefan Schönert, a spokesman for the detector. Built underground, the detector is now filled with water, which provides a shield from external gamma radiation and neutrons from the surrounding rocks.

PHOTO: E VANDEVILLE/GRAN SASSO



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Rouge Rhône

THIS MAY LOOK like a scene from an exotic exoplanet, but it's actually the edge of a small lake in the Rhône delta in southern France.

The white substance seen clinging to the shoreline and to the twigs is common salt, which has evaporated out of the lagoon's incredibly salty water. The water appears red as an indirect result of its extreme saltiness: the colouration is caused by the high levels of halophilic – or salt-loving – microorganisms that live within it. Similar colouration can be seen in other salt-saturated waters around the world, such as Great Salt Lake in Utah.

"The colour of such hypersaline brines is in part caused by the unicellular alga *Dunaliella salina*, which is high in beta carotene," says Prof Aharon Oren of the Hebrew University of Jerusalem. "Other organisms can also be involved, such as a bacterium named *Salinibacter ruber*. They have a high concentration of carotenoid pigments in their cell membrane, which helps protect them from UV radiation."

PHOTO: SAM DOBSON/CATERS

REPLY

Your opinions on science, technology and our last issue

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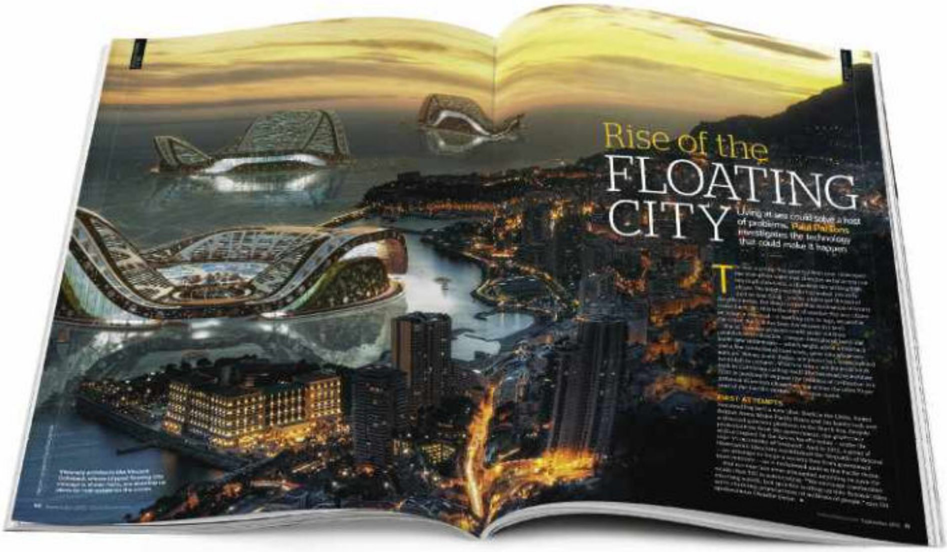
MESSAGE OF THE MONTH



Would you buy property on a floating city? We looked at this possibility in our September issue

Cities all at sea

I receive your magazine monthly and find it fascinating and inspirational. However, I read with horror the article on floating cities in your September issue (p60). As a retired marine engineer I cannot begin to imagine the practicalities of locating people to offshore cities, safely. If there are any doubts, google 'sinking semi-sub' and be amazed at the number of offshore installations that slip beneath the waves on a regular basis! The sea is a harsh environment. Building real estate at sea that has a life expectancy of only 30 years cannot be viable – you wouldn't build a city on land that only had a life of 30 years!

The United Nations IMO (International Maritime Organization) would impose legislation on these proposed structures, and classification societies would not insure them if they were not built to stringent regulations. The dream of bypassing governments, bureaucracy and red tape to build these cities and further mankind is an illusion. Huge passenger ships today are dependent on the land for repair/dry-docking, logistics of food, fuel, waste management etc, so these cities would not be independent of the land. If they are centres of unrestricted commerce, they would be targets for terrorists and pirates. I will keep my feet on land thank you...

Michael Mahon

I wouldn't disagree with you, but the organisations involved seem serious about their projects. – Ed

Write in and win!

Michael Mahon wins a copy of *Deadly Top 10* (BBC DVD, £10.20) presented by Steve Backshall. Send us your views to win next month's prize.

Loving the new look

The new layout is a great improvement over the old one, much easier to navigate and having the 'Reply' section first makes it much easier to relate readers letters to the articles they mention (as they are usually to do with the previous issue). Good job!

Alex Jones, Warwick

Thanks for the memories

First of all, congratulations – *Focus* has really returned to form in the last few issues. 'The Masters Of Memory' in issue 246 was typically fascinating, however I feel one important area was left out – the mechanism that causes us to remember to do things, eg to post that letter that we have in our pocket when we pop down the shops. Or, more to the point, why do I usually find it still in my pocket when I get home?

Oli Cooke, Weybridge

My first comment is that 'The Masters Of Memory' (September, p54) was excellent! Now, since the writers appear to be opting for the various digital memory devices, why don't they give a little more attention to digitalising people's brains? That idea was suggested several centuries ago with, as expected, zero results. Today there are millions of 'bright sparks' that I'm sure could begin to digitalise people's brains. If such digitalisation was not highly successful, at least they will surely develop some means of overcoming

Don't look at the light! Will Smith uses memory manipulation in *Men In Black*

PHOTO: KOBAL, ESO

the shortcomings. The basic aim is to download peoples' brains (most likely to be when they die, but sooner would be best). Many medical tests prove that the brain can be very useful when digitally testing them (usually via computer program). The amount of data that could be revealed to all would be huge – would you like to read all of the data that Stephen Hawking could pass on if his brain was downloaded after his death? (You can have all of mine for nowt!!).
Ray Thomas

I used to think decoding information from our brains was far-fetched. But then I read about research at the University of California, whereby scientists were able to reconstruct movie trailers by scanning volunteers' brains, as those volunteers watched video clips. See http://bit.ly/pH6NQR for more on that work. – Ed

Big Brother on Mars

Would it not be an excellent idea to publish an article devoted to entrepreneur Bas Lansdorp's Mars One project? As you may or may not know, Mars One plans to place humans on Mars, but not on the back of government funding, tax payers' money or individual private investors. Instead, it aims to create a *Big Brother*-style media spectacle like none seen before. The astronauts will be 'auditioned' and then chosen (presumably through voting) by the public. This is, of course, a totally different approach to almost all other space expeditions in the past, but as Mars One points out, is perhaps the only way humans could currently reach Mars.

The plans of the project itself, as well as the ethical and financial questions which are raised, would make for a compelling article. And of course, projects such as this are essentially reliant on the exposure that this magazine can offer, in order to make progress.
David Bissell

Thanks for the suggestion David. In our November 2011 issue, we looked at ESA's Mars500 project, which simulated a mission to the Red Planet. – Ed

YOUR COMMENTS ON FACEBOOK

On facebook.com/sciencefocus we asked:

Scientists at UCL can turn off our in-built 'optimism bias', which makes us more rational, by exposing parts of the brain to a magnetic pulse. A good idea?

Clyde Meli Making people negative is not being 'rational' or 'realistic'... no I would not use this gadget.

Flis Eames No! It sounds like a surefire route to depression & apathy.

Mark Stuckey Step one towards mind control...

Limb regrowth

We've recently seen some great stuff from paralympians (I was lucky to watch the wheelchair basketball at Greenwich Arena). No one though has asked, to my knowledge, 'How long until our scientists can crack regrowing limbs?' With stem cell technology emerging, surely an investment drive in this area will give so many the hope of a full-bodied life?
Phil Wilson

Regenerative medicine is an active area of research Phil – indeed, we covered it in our August issue feature, 'Grow Your Own Body'. – Ed

Interstellar traveller

In reply to Stuart Moyles' comment (October, p15) about the disappointment of reaching another star system with no life-supporting planets: in the time it takes to get there, a planet within the Goldilocks orbit around a star could have had several civilisations and ecology restorations in that time. Any interstellar travelling would have to take that into consideration wherever we go.
Geoff Willmetts, Bridgwater

Civilisations could come and go on an alien world in the time it takes for us to travel there

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News and views from the world of science

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WEIGHING THE INVISIBLE

Invented: a nano device that can measure the mass of individual molecules

MICROSOFT'S HOLODECK

Tech giant aims to turn your living room into a game world

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PONYTAIL SCIENCE

A study of hair fibres has won a coveted Ig Nobel prize

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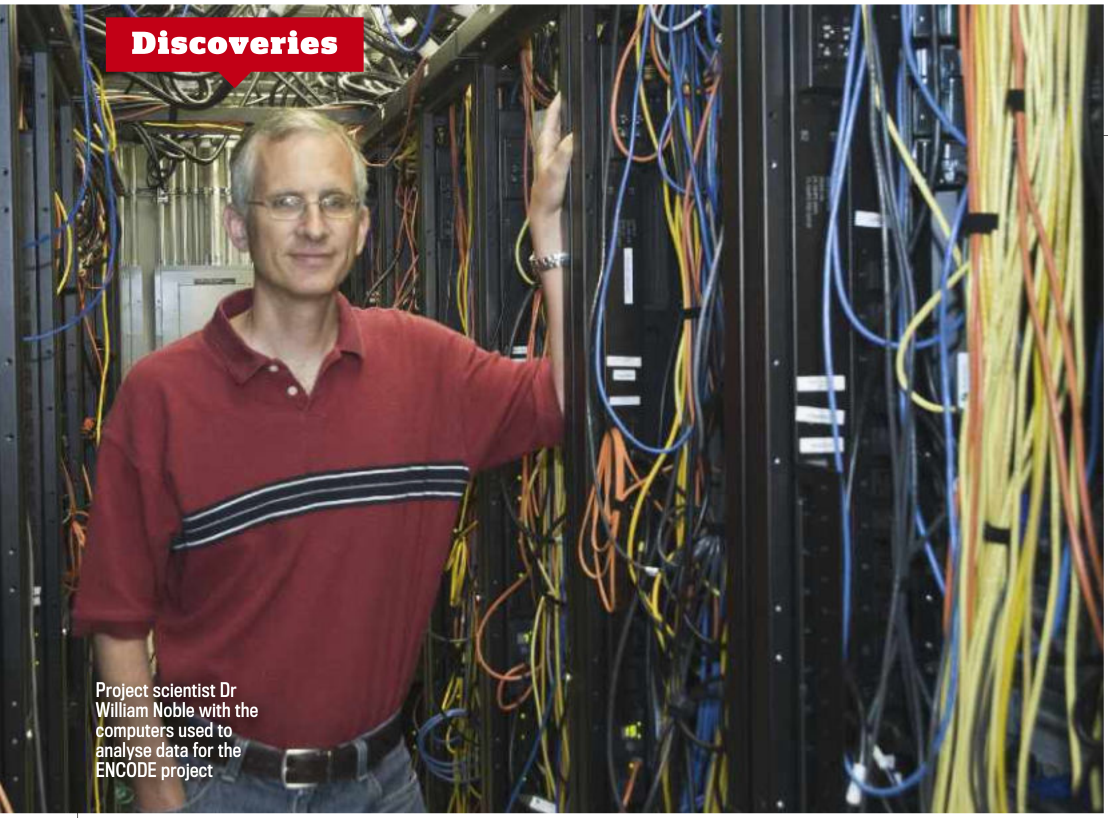
The Human Genome Project sequenced our DNA - now ENCODE takes a closer look

PHOTO: CORBIS

THE BIG STORY

Human DNA encyclopedia published

Huge study identifies millions of switches that control our genes



Project scientist Dr William Noble with the computers used to analyse data for the ENCODE project

THE STRETCHES OF DNA that populate the regions of genetic code between our genes have been surveyed comprehensively for the first time, providing the clearest insight yet into what they do. A high proportion of this genetic material had been considered ‘junk’ by some scientists, but an international research effort has revealed how important it is in shaping who we are and our susceptibility to disease.

The Encyclopedia of DNA Elements, or ENCODE, has cost over $185m (£114m) and taken 400 scientists five years to compile. It shows that 80 per cent of DNA in the human genome has some purpose – a far cry from the notion that the majority of it is junk.

ENCODE picks up where the Human Genome Project (HGP) left off. The HGP revealed the three billion molecules, or ‘letters’, that make up the human genetic code, including the regions that encode proteins – the genes. But genes make up little more than one per cent of the genome and ENCODE, whose results have just been published in 30 scientific papers, reveals what the rest of our DNA does. It shows how many sections of this DNA exert control over our genes – switching some on and others off.

“We always knew that hair and liver cells were different, so we knew there must be something switching things on and off,” says Dr Ewan Birney, the British computational biologist who coordinated the data analysis for ENCODE. “I always imagined something quite well ordered, with a number of switches quite close to each gene. But the genome is full of them – we found four million – and they’re spread quite evenly throughout the genome. It really feels like a jungle.”

To work out where these switches are, the researchers analysed where proteins known as transcription factors bind to DNA and where other biochemical changes take place – indicating the genetic material is active. By comparing which regions are active in different cell types, researchers can infer what they do. “I’m excited about how ENCODE will help disease research,” says Birney, who works at the European Bioinformatics Institute in Cambridge.

So far, the ENCODE researchers have studied 116 transcription factors out of roughly 2,000, and 187 cell types out of roughly 1,000. The next phase is to look at all transcription factors across all cell types.

ANDY RIDGWAY

ANALYSIS

Anne Ferguson-Smith

Professor of Developmental Genetics at the University of Cambridge

“ENCODE is hugely important. Understanding the protein-encoding aspect of the genetic code is actually relatively simple, but it doesn’t tell you how the code works. Our genes are controlled by other genetic material. ENCODE is an important catalogue of regulatory elements. It will help us understand the role these elements play in contributing to disease.

One of the things that’s special about this research is its scale. It’s been done on a large number of different cell types, so the correlations are strong. They compared so many cell types they can identify that a particular part of the genetic code is associated with gene activation or repression in certain cells but not in others.

We are interested in epigenetic marks – places where there are chemical modifications to DNA and the proteins that wind up chromosomes – and how they regulate genes. ENCODE shows where some of these marks are in multiple cell types, and whether they are associated with gene activation or repression. However, it doesn’t tell us whether these modifications *cause* a change in gene expression – there’s just a correlation. But we can design experiments to test whether or not the links are causal.”

WHAT DO YOU THINK?

Let us know your thoughts at facebook.com/sciencefocus

TIMELINE

Unravelling our genetic code

1972

Working with a virus, biologist Walter Friers becomes the first person to determine the full list of molecules, or letters, that make up a gene.

1988

The human gene that encodes the CFTR protein is sequenced by geneticists Francis Collins (right) and Lap-Chee Tsui.

2003

The Human Genome Project is completed, determining the sequence of letters that make up human DNA. It identifies 20,000-25,000 genes.

2003

International research effort ENCODE is launched, with the aim of cataloguing the functional DNA sequences that lie between our genes.

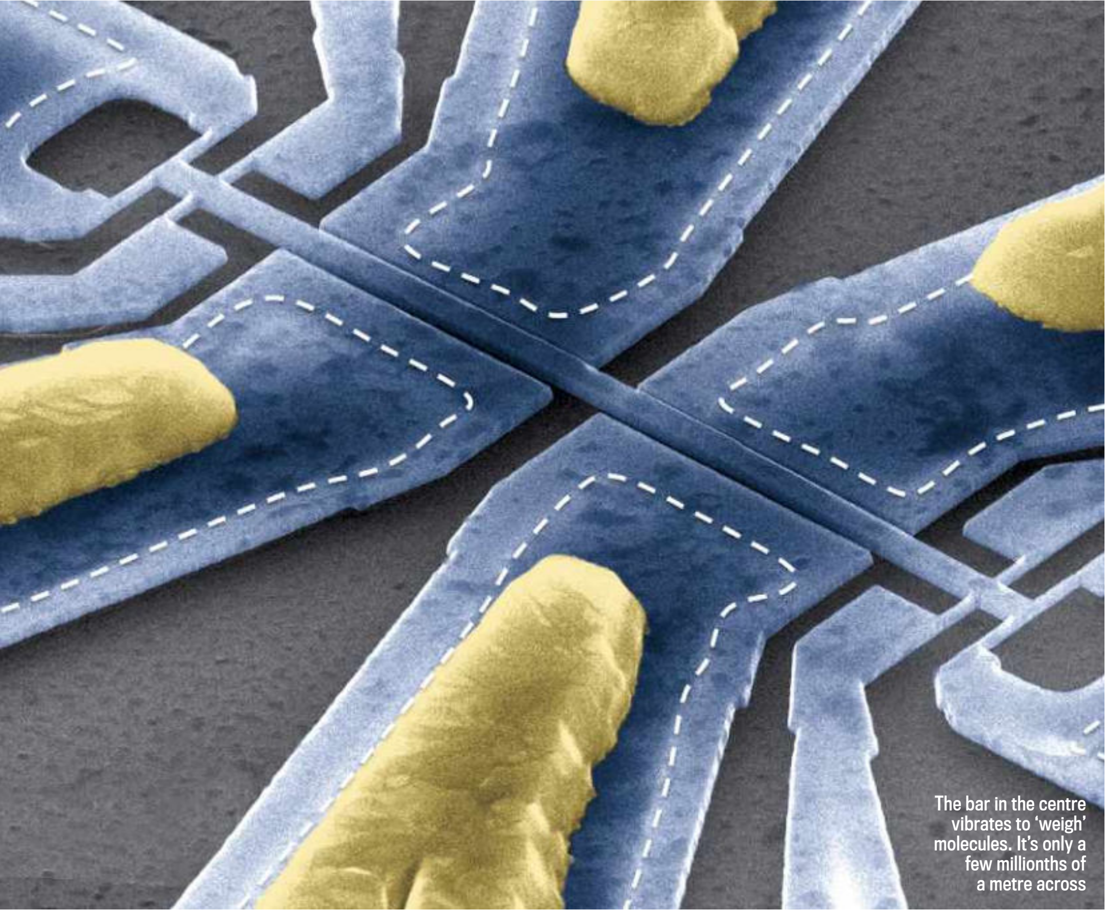
2007

The results of the ENCODE pilot project, which looked at just one per cent of the human genome, are released.

2012

ENCODE gives the clearest picture yet of how genes are controlled by the rest of the DNA. Pictured: Project scientist Dr Stamatoyannopoulos.

PHOTO: GENOME RESEARCH LIMITED, CLARE MCLEAN/UNIVERSITY OF WASHINGTON, GETTY



The bar in the centre vibrates to 'weigh' molecules. It's only a few millionths of a metre across

Nanotechnology

The weigh forward

SET TO PROVIDE insights into everything from the workings of cells to air pollution, a new device can weigh molecules one at a time. The weighing scale consists of a bridge-like silicon structure that's 300 times narrower than a human hair. The bridge vibrates, and changes in the frequency of the vibration as molecules land on it reveal their mass.

Molecules are typically weighed using mass spectroscopy, in which tens of millions of them are ionized and then interact with an electromagnetic field. Analysing this interaction allows scientists to deduce a molecule's mass. But the technique doesn't work well for more massive particles such as proteins or viruses. That's where the new device, a nanoelectromechanical system (NEMS) resonator, will come into its own.

"You can think of what we're doing as electrically stimulating a little violin string," says Prof Michael Roukes at California Institute of Technology. Like a violin string, the beam's vibrations are a mixture of different motion patterns, or 'vibrational modes'. In one mode, the entire beam bends from side to side; in a second, the two halves bend in opposite directions with the midpoint fixed. By analysing the shifts in frequency of these two modes, the researchers can work out the particle's mass and position.

"As our mass sensitivity increases we want to focus on studying the plasma proteome – the proteins circulating in our blood system," says Roukes. Examining this protein set would provide an instant snapshot of someone's physical condition. Larger particles could also be weighed, including air pollution molecules and viruses.

JAMES LLOYD

1 MINUTE EXPERT

Voyager 1

Where is Voyager 1 now?
Launched in 1977, Voyager 1 is now the furthest spacecraft from Earth. It is 18 billion kilometres (11 billion miles) away, in a turbulent region where the Sun's influence ends and particles from the Sun crash into the thin gas that pervades interstellar space.

What is it doing there?
Along with its sister craft Voyager 2, Voyager 1 is on a one-way mission to interstellar space. Scientists are monitoring signals to work out how far it is from the edge of the Solar System.

When will Voyager 1 leave the Solar System?
It could be days, months or years. Scientists are looking for three key signs: a jump in cosmic rays from outer space, a drop in the level of particles from our Solar System and a change in direction of the magnetic field. In July, they saw two of the three key signs. Now they are waiting for the third.

What will happen then?
Voyager 1 will be the first human-made object to leave our Solar System, and we should still be in contact with it when it does. Voyager 2 should follow soon after. Voyager 1's plutonium power reserves will last until at least 2025, at which point we'll lose contact with it. Follow their progress at http://voyager.jpl.nasa.gov/where/index.html

KELLY OAKES

WHO'S IN THE NEWS?

Catherine 'Cassie' Conley

NASA Planetary Protection Officer

What did she say?
Conley's job is to ensure that NASA doesn't contaminate any environment it explores with microbes from Earth. So she wasn't too pleased to learn that a sterilised box of Curiosity drill bits had been opened six months before lift-off. "They shouldn't have done this without telling me," she told the *Los Angeles Times*. "It is not responsible for us not to follow our own rules."

Will this cause problems?
If the rover encounters water, yes. If the contaminated drill bits touch it, the microbes could survive. Conley's predecessor Dr John Rummel, a biology professor at East Carolina University, said: "It will be a sad day for NASA if they do detect ice or water, because Curiosity will most likely be told, 'Gee, that's nice. Now turn around.'."

So why was Curiosity's box of drill bits opened?
Engineers got worried that a heavy landing could damage the drill, so they decided to mount one bit in advance. Other NASA officials have described the move as a calculated risk.

PHOTO: SCOTT KELBER/MICHAEL ROUKES/CALTECH, NASA

PATENTLY OBVIOUS

Inventions and discoveries that will change the world with James Lloyd

Microsoft goes to the wall

HIGH-RES GRAPHICS and motion controls have made gaming an increasingly realistic experience, but now Microsoft wants to take things a step further – by completely filling your living room with the action. The US computing giant has applied for a patent for its technology that can project the gaming environment, be it a war-ravaged island or Silverstone motor racing circuit, onto all four walls of a room.

A 'depth camera' will generate a 3D representation of the room and, while the heart of the action will still take place on a TV screen, the wider scene will appear on the surrounding walls (and presumably potted plants). You would then be able to see a racing car poised to overtake out of the corner of your eye, or turn around to catch an enemy soldier sneaking up from behind.

Microsoft hopes to incorporate a user-tracking device, similar to the one that appears in the Xbox Kinect, into the technology. This would identify your position and prevent the image from being projected onto your body or into your eyes. It's not quite the holodeck from *Star Trek*, but it's a promising start nonetheless.

Patent application number: US 20120223885

Tool to tame storms at sea

FINDING A WAY to calm hurricanes could save thousands of lives and prevent billions of pounds worth of damage. Now, an inventor in Mexico City has patented a device he hopes will do just that.

Jose Cherem Haber's contraption consists of a number of interconnected slabs, forming a floating network covering one square mile of ocean. In the event of a hurricane the slabs, constructed out of a buoyant material such as rubber or plastic, would be towed into the storm's path by a fleet of unmanned, remote-controlled ships.

According to its inventor, the system would weaken the force of the storm by creating a barrier between the ocean and atmosphere, preventing the rise of the warm, moist air that's crucial to hurricane formation.

Patent application number: US 8256988

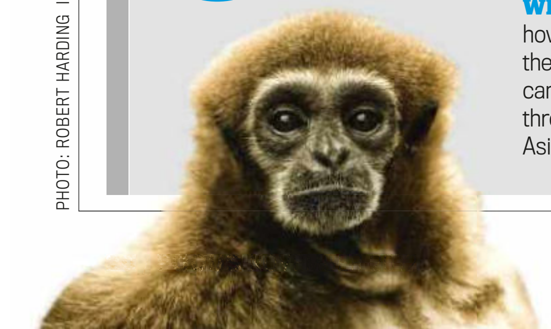
Cat's eyes get smart

CLEARVIEW TRAFFIC GROUP'S new patent application envisions smart cat's eyes for the road containing a light sensor, a processor and a light source, as well as the usual reflector. This would enable the cat's eyes to monitor light from cars and calculate how much extra light to emit. Each driver would then see the same amount from a cat's eye, regardless of how bright their headlights are.

Patent application number: GB 2487674

THEY DID WHAT?

Gibbon put on helium



What? Japanese scientists took a white-handed gibbon (*Hylobates lar*) from Fukuchiyama City Zoo, north of Kyoto, and exposed it to helium.

Why? They were investigating how these primates generate their distinctive call, which can penetrate 2km (1.2 miles) through the dense forests of Asia where they live.

What did they find? Helium doesn't affect the location where sounds are produced (the gibbons' vocal folds). But it does change the frequency at which the vocal tract resonates – producing the same squeak as in humans.

So what does it mean? Humans were thought to be unique among primates, producing sound in one location, the larynx, and modifying it in another, the vocal tract. But the research in Japan has shown that these gibbons employ the same two-part mechanism. The similarities don't end there. Like soprano singers, gibbons tune the resonant frequency of their vocal tract to the pitch frequency generated by the vocal folds to amplify the sound.

PHOTO: ROBERT HARDING ILLUSTRATION: ROBIN BOYDEN

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*Based on Battery-Back sample data of 3,149 batteries (AA/AAA/C/D) sent to be recycled in the UK in November 2011.

Holding a ponytail in triumph, Prof Goldstein celebrates his Ig

Physics

Science with a twist: ponytail physics wins an Ig

THOUGH 2012 IS likely to go down as the year the Higgs boson was discovered, four scientists will remember it as the year they were feted for cracking the physics of ponytails. A British-American team has discovered how gravity, hair stiffness and curliness interact to determine the hairstyle's shape, and their efforts have earned them an Ig Nobel prize. The Igs, organised each year by US science-humour magazine *Annals of Improbable Research*, honour work that "makes people laugh and then think".

The physicists were set the challenge of studying ponytails by Unilever, a company that sells hair care products. They first developed a 3D imaging system to observe the properties of individual hairs. This allowed them to develop a Ponytail Shape Equation that describes the collective properties of the bundle. Such an equation would come in handy to fabric manufacturers who want to predict the properties of many fibres drawn together, and could allow animators to develop more realistic hair for their characters. "Hair is one of the parts of the body that is notoriously difficult to portray accurately by a computer animator," says Prof Robin Ball, a statistical physicist at the University of Warwick.

The Ig Nobels celebrate 'silly' research with a serious purpose

Ball, University of Cambridge physicist Prof Raymond Goldstein and Unilever physicist Dr Patrick Warren weren't the only ones recognised for hair-related research at the award ceremony at Harvard University. Dr Joseph Keller, Professor Emeritus of Mechanical Engineering at Stanford, also won for his work on the motion of ponytails.

Other 2012 Ig Nobels were handed to US neuroscientists who measured brain activity in a dead salmon, and a team of zoologists who found chimpanzees can identify their contemporaries from photos of their rear ends. For more details, see bit.ly/HLScuD

ZOE CORMIER

PHOTO: REUTERS, NICK HOBGOOD, PRESS ASSOCIATION ILLUSTRATOR: HITANDRUNMEDIA

DIGITAL WORLD

Science on the web

LAKE ELLSWORTH

www.ellsworth.org.uk

In October, British scientists and engineers made their way to Lake Ellsworth, a Windermere-sized body of water hidden beneath 3.4km (2 miles) of Antarctic ice. By December they hope to be bringing samples to the surface, in the hope of discovering ancient life. The website will have updates on how they're getting on.

GALAXY ZOO

galaxyzoo.org

Want to see your name in lights? Galaxy Zoo has a new tool that lets you write a message in real galaxies that look like letters. The site's creators have just added 250,000 new galaxies that need to be classified, too, so if you'd rather help out with some serious science instead there's plenty to be getting on with.

Few have witnessed what you're about to see

Classify Galaxies

How Do Galaxies Form?

History of Galaxy Zoo

Galaxy Zoo is a serious 'citizen science' project, but it has a lighter side as well

ENGINEERING SPORT

richannel.org/collections/2012/engineering-sport

Top athletes can't just train harder – they need to train smarter. This series of videos shows how technology is used to improve an athlete's performance, from giving feedback on diving moves to coming up with a Grand Unified Theory of tennis.

HERE, THERE AND EVERYWHERE

http://hte.si.edu

From bow shocks during your morning swim to electrons colliding in a neon sign, the laws that govern stars and galaxies apply down on Earth too. This new site, developed at the Chandra X-ray Center in Massachusetts, shows that physics isn't all about the Big Bang and tiny Higgs bosons.

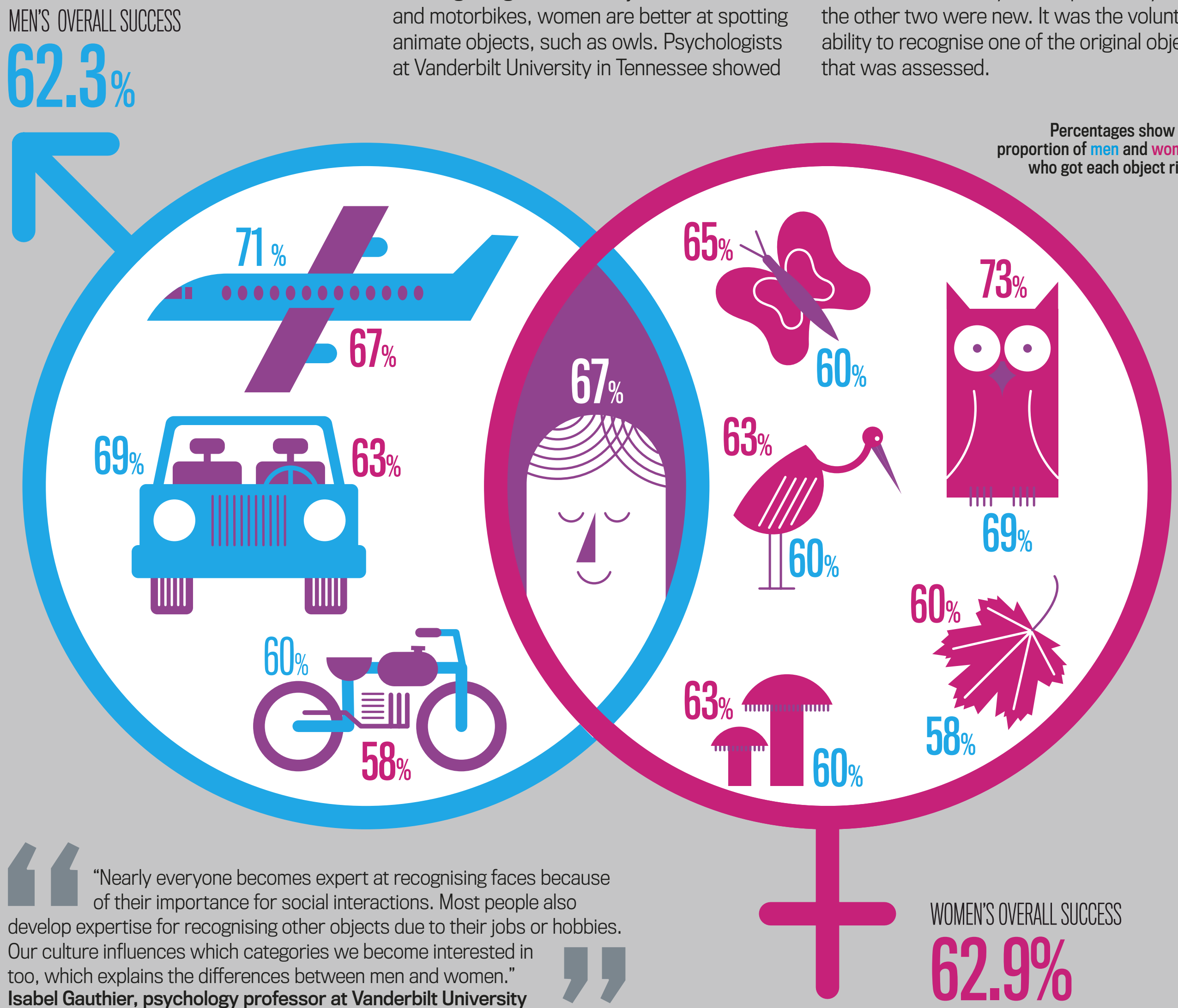
KELLY OAKES

GRAPHIC SCIENCE

Seeing research differently

HOW SEXES SEE THE WORLD

When it comes to recognising things, men and women are worlds apart. While men are good at recognising inanimate objects such as cars and motorbikes, women are better at spotting animate objects, such as owls. Psychologists at Vanderbilt University in Tennessee showed men and women images of different objects. They were then shown three different images of the same kind of object (an owl for instance) at the same time. One of the three was the same as the one they'd seen previously, while the other two were new. It was the volunteers' ability to recognise one of the original objects that was assessed.



Percentages show the proportion of men and women who got each object right

> "Nearly everyone becomes expert at recognising faces because of their importance for social interactions. Most people also develop expertise for recognising other objects due to their jobs or hobbies. Our culture influences which categories we become interested in too, which explains the differences between men and women."
> **Isabel Gauthier, psychology professor at Vanderbilt University**

NEWS IN BRIEF

Seasquirts aid future PCs

Lissoclinum patella seasquirts in the Great Barrier Reef produce the molecule patellamide, which can take on two different forms and therefore act as a simple switch. Scientists at the University of Aberdeen are now working on developing the molecule so it can replace the silicon atoms used in traditional transistors, with a view to building smaller, faster PCs.

The next big leap forward in computing could depend on this little fella, the seasquirt

Flu virus spreads early

Flu can be passed on before its symptoms appear – at least, it can in ferrets. Researchers at Imperial College London discovered that ferrets transmit flu within just 24 hours of becoming infected – many hours before they begin to exhibit feverish symptoms. If the same proves true for humans, this would make it even more difficult to control epidemics.

Gravity waves 'seen'

A pair of white dwarf stars has provided new evidence for gravitational waves – ripples in space-time caused by moving objects that should, according to the General Theory of Relativity, cause objects orbiting one another to move closer together. Now, a team led by University of Texas at Austin astronomers has spotted two white dwarfs doing just that.

STOP THE CULL!
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Brian May is a vocal critic of the badger cull

HOT TOPIC

Should the badger cull go ahead?

AFTER NUMEROUS studies, licences are being issued to carry out badger culls in England. As *Focus* went to press, government advisory body Natural England had issued a licence to landowners in Gloucestershire to carry out a cull and another was expected to be issued to farmers in Somerset. The culls are aimed at controlling the spread of TB in cattle.

Around 26,000 cattle were slaughtered in England last year to control TB, and badgers carry the disease. Over 10 years ago, the government ran a cull trial in 30 areas of 100km^2 in England. It showed that if more than 70 per cent of badgers in an area are killed, cattle TB infections will fall. But it also showed that badgers range more widely during a cull, and so the incidence of TB can rise around the cull zone.

Lord Krebs, a government scientific advisor and the author of a report into badger culls, has said that the Department for the Environment, Food and Rural Affairs (Defra), which is administering the cull, has no way of knowing how many badgers there are in an area, and so will not know when 70 per cent have been killed. Defra has said that it will commission its own research to estimate badger numbers.

WHAT DO YOU THINK?

Let us know your thoughts using the hashtag **#hottopic** at **twitter.com/sciencefocus**, and on **facebook.com/sciencefocus**

Your Tweets and Facebook posts

Peter Mitchell: *No. The cattle should be the focus of deliberate vaccination. After all, it's not just badgers that carry TB.*

Rob Ford: *No, of course not! We should start with the human race for widespread stupidity.*

Stephen Towler: *Only if the people cull goes ahead first!*

Jules Connor: *Culling on this sort of scale seems a tad primitive, and doing so without fully understanding the sources of infection smacks of knee-jerkism to me.*

PHOTO: PRESS ASSOCIATION

WHAT THE PAPERS SAY

HENRY GEE

New research from leading science journals

Our sight wins in the battle of our senses

WHAT IS A film, these days, without a soundtrack? Movies are immersive experiences in large part because of their music. Would *Star Wars* be as memorable without the likes of the *Rebel Fanfare* and *Princess Leia's Theme*?

Ever since the days of silent movies, when films were accompanied by live musicians, film composers have known how to add to the action. This is why love scenes have syrupy strings, but violence and horror are accompanied by edgy, often dissonant themes, full of unexpected intervals and clangorous, inharmonious textures. The screechy, stabbing violins in the famous shower scene in *Psycho* are a classic example. But does this work in the opposite direction? Does the film we see influence our perception of the music we hear? Would the soundtrack for *Psycho* seem less disturbing were it dubbed onto home videos of fluffy kittens?

In new research published in the journal *Biology Letters*, two University of California, Los Angeles scientists were joined by film composer Peter Kaye to find out. They first played a bunch of volunteers a selection of emotionally neutral music without any distortion or sudden changes in pitch. People (and animals) perceive sounds as euphonious and 'friendly' if they have some clear mathematical relationship to one another, such as octaves (two notes, one with a frequency twice that of the other), fifths, fourths or thirds. But they perk up – and perhaps express dislike – at the clashing dissonances of seconds, diminished or augmented chords.

When noise and unusual intervals were added to the muzak in California, the volunteers were more likely to express displeasure – as you'd expect. But when the same music was used to accompany what's described as a 'benign' video of people doing ordinary, humdrum stuff – like reading a newspaper or walking along a street – the subjects were less likely to be put off the music.

We are visual animals, and happy sights trounce disturbing sounds. The researchers are at a loss to explain why visual stimuli suppress the disturbing effects of sound, though it could be a matter of simple distraction. But it could explain why dentists often have tanks of tropical fish – to distract waiting patients from the distressing screams and sounds of drilling. And why things that go bump in the night are more frightening in darkness.

Could this research inform other aspects of our everyday life? If you suddenly start seeing attractive shrubs planted at motorway junctions, or videos of fluffy kittens being played in noisy factories, you saw it here first.

Henry Gee is a palaeontologist and evolutionary biologist, and a senior editor of the journal *Nature*

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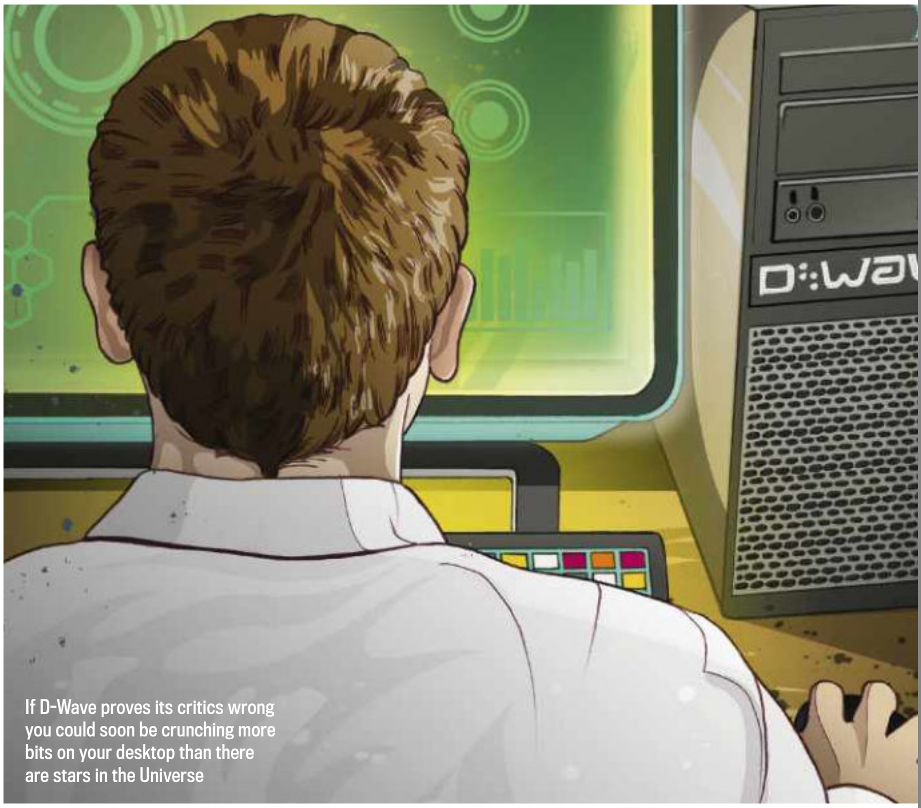

If D-Wave proves its critics wrong you could soon be crunching more bits on your desktop than there are stars in the Universe

BUILD A BETTER mousetrap, the saying goes, and the world will beat a path to your door. Don't count on it, though – especially if you're claiming to have succeeded where other scientists have failed. Just ask the guys at D-Wave. For years, this small Canadian company has been claiming to have created one of the Holy Grails of 21st Century technology by building the world's first practical quantum computer. It's quite a claim, because such a machine is expected to be able to solve in milliseconds problems that would take millennia on any conventional computer.

This awesome power comes from swapping the simple on/off binary digits – the 'bits' – used by ordinary computers for their quantum counterparts, known as qubits. These exploit sub-atomic effects that enable each qubit to represent many numbers simultaneously, making them hugely efficient at number-crunching. A quantum computer using just 100 qubits could handle problems involving more bytes of data than there are stars in the Universe.

Well, in theory – and 'in theory' is where quantum computers have largely been stuck for decades. The effects they rely on are very delicate and scientists have struggled to get them to do anything interesting.

Small wonder, then, that when D-Wave unveiled what it called the world's first useful quantum computer last year, there was less than universal celebration. Academics said the D-Wave One machine wasn't a pukka quantum computer, claiming that it wasn't really using qubits but some more stable, less powerful, substitute.

D-Wave has worked hard to prove it knows what it's doing – and now hopes to convince others by using its machine to solve a tough problem in biochemistry. Many diseases, such as Alzheimer's, are linked to proteins made by our cells, and scientists have long sought ways of predicting protein behavior just from knowing what they're made of. But the link between the two is complex and needs massive computing power to reveal – which makes it an ideal test-bed for any would-be quantum computer.

Now D-Wave says its D-Wave One machine has successfully predicted the behaviour of a protein. Okay, the protein was so simple even a laptop could have done the same. But the company insists it's now just a matter of time before its machine will tackle problems that would fry a conventional computer. Needless to say, the critics aren't buying it.

> **"The company insists it's now just a matter of time before its machine will tackle problems that would fry a conventional computer"**

They're still insisting that until the company demonstrates real quantum computing effects, such as the delicate 'entanglement' between qubits that gives them their number-crunching power, the D-Wave One must still be regarded as a bog-standard computer with go-faster stripes. Is that fair? Maybe, maybe not – but it seems irrelevant. For who cares if someone has built a faster computer whose methods are doubted by some, as long as it is faster?

There are parallels here with a bitter controversy that once surrounded another breakthrough: the aeroplane. In 1903 the Wright brothers did the seemingly impossible and got a heavier-than-air machine to fly. It didn't fly very far, just a few hundred metres, but it still provoked incredulity. Academics were locked in arguments over how such a machine could get off the ground, while engineers just tried ideas that seemed to work – and created the aviation industry. Even today, the equations underpinning flight have never been fully solved, but that hasn't stopped people travelling by air.

Fortunately, not everyone is refusing to take D-Wave seriously until the academics give their approval. The company has now sold its first D-Wave One. Aptly enough, the customer is Lockheed – best known for building those 'impossible' things called aircraft. ■

ROBERT MATTHEWS is Visiting Reader in Science at Aston University, Birmingham

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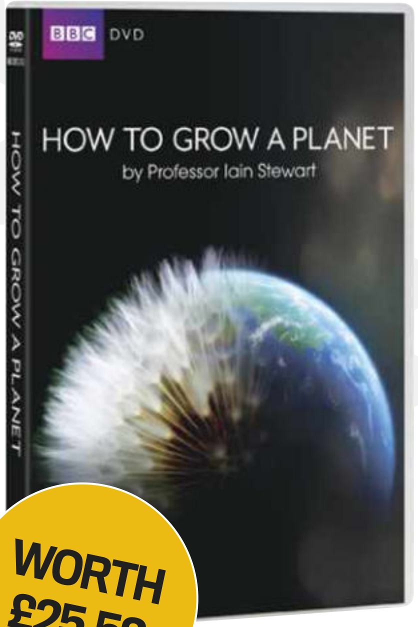

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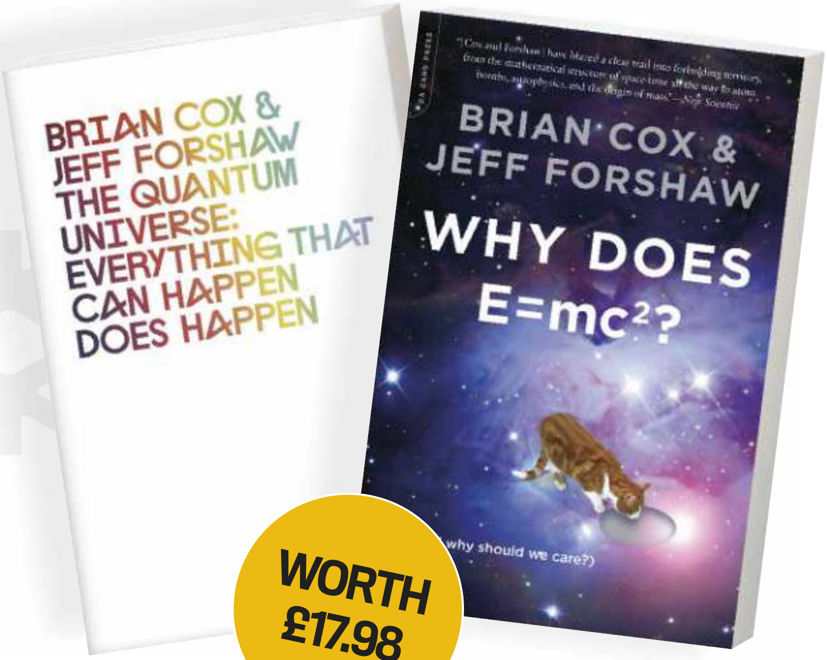

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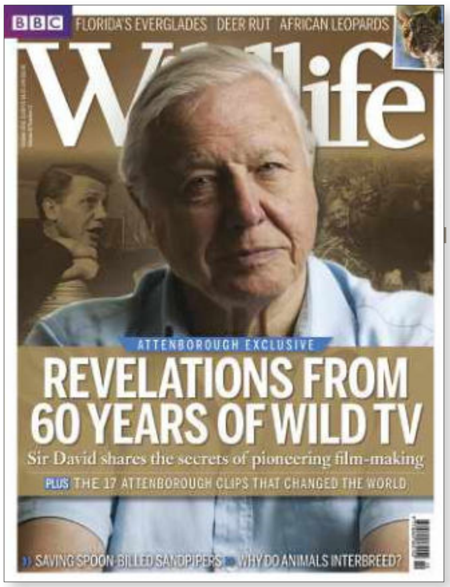

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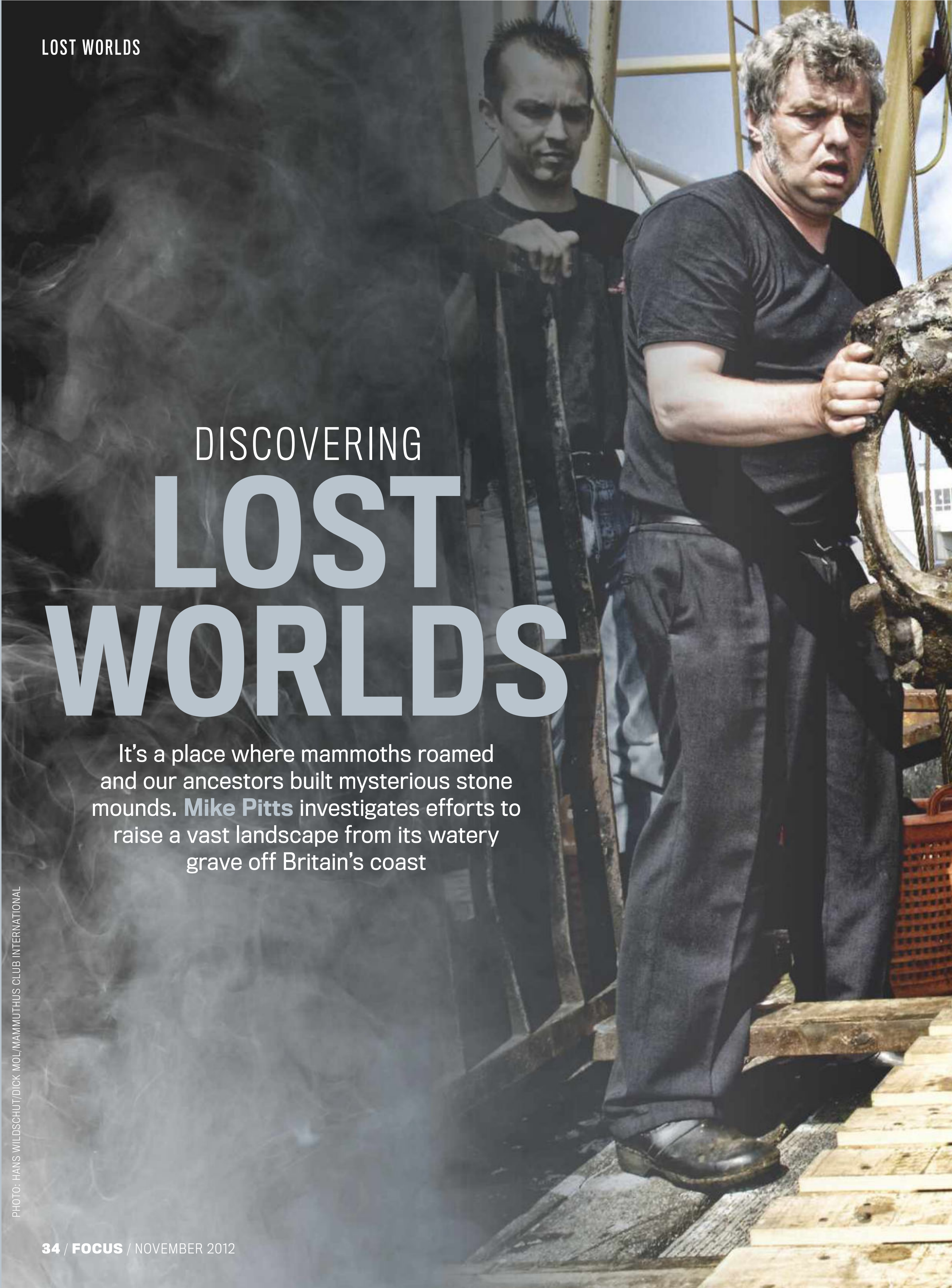
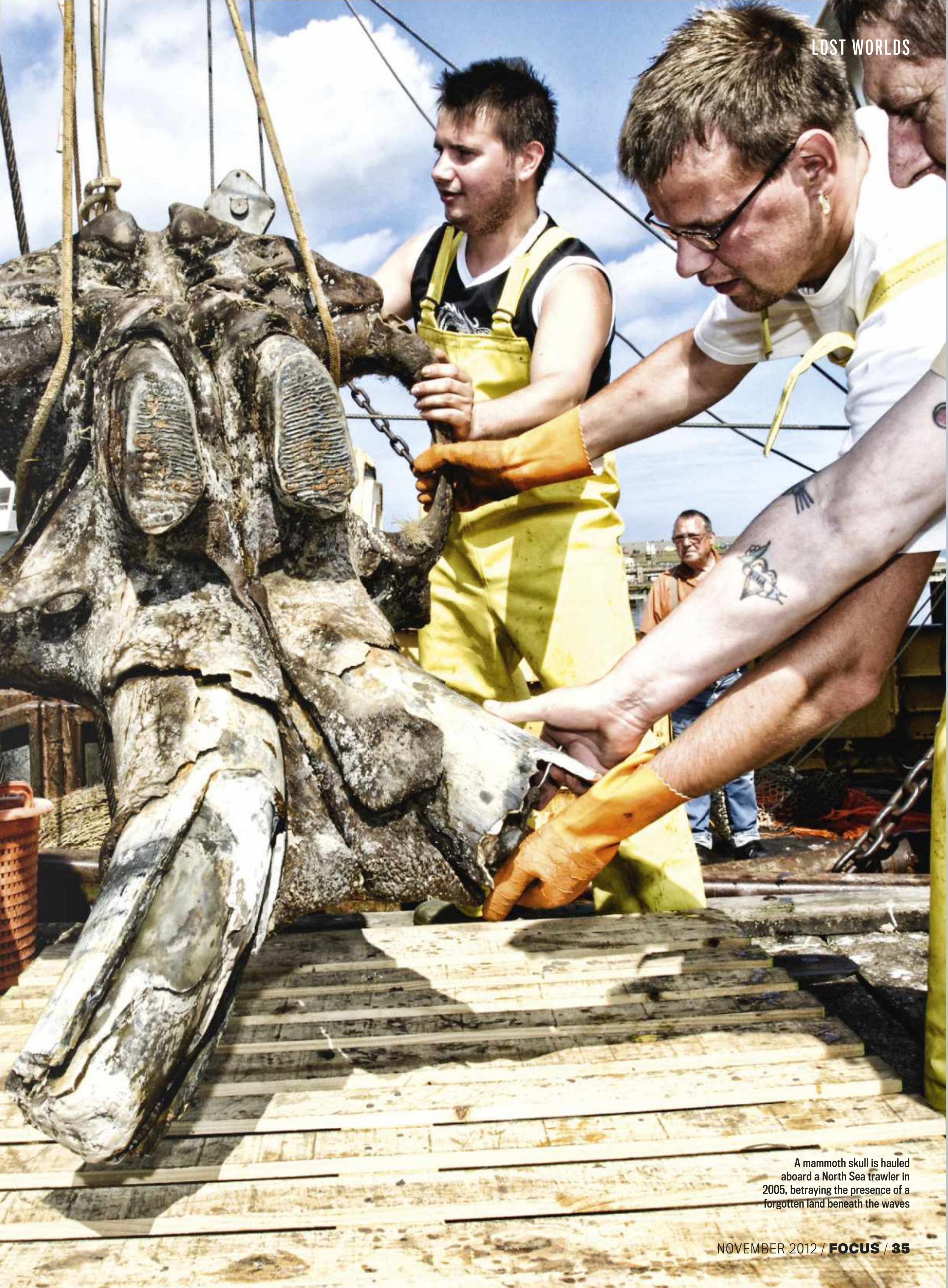


DISCOVERING LOST WORLDS

It's a place where mammoths roamed and our ancestors built mysterious stone mounds. **Mike Pitts** investigates efforts to raise a vast landscape from its watery grave off Britain's coast

PHOTO: HANS WILDSCHUT/DICK MOL/MAMMUTHUS CLUB INTERNATIONAL



A mammoth skull is hauled aboard a North Sea trawler in 2005, betraying the presence of a forgotten land beneath the waves

PHOTO: NORWICH CASTLE MUSEUM AND ART GALLERY, HAMPSHIRE & WIGHT TRUST, MARTIN BATES X2 MAP: MARTIN SANDERS

Denis Bates was walking on the Ceredigion Coast Path at Borth in west Wales. The tide was out and he was no casual visitor. A retired Aberystwyth University geologist, he knew that beyond the sands lay a submerged forest: miles of stumps and fallen trees, preserved by waterlogged peat. He went out to explore.

On his outing in February, Bates found a scatter of burnt stones in the mud, and phoned his son. Martin Bates is a University of Wales archaeologist down the road at Lampeter and with his other son Richard, a geophysicist, they set out to investigate. They recorded signs of cattle, horses, sheep or goats, and people – including the footprints of a young child. Martin reckons the finds are Bronze Age, some 3,500 years old. Perhaps, he muses, children were tending animals around a water hole in the forest.

But this is not the only location off the British coast where there are clear signs that what is now sea was once land. And many of the artefacts discovered have been as intriguing as the footprints at Borth. Stone mounds – apparently created by human hand – have been found off the coast of Orkney and tonnes of land animal remains, including mammoth bones, have been hauled from the North Sea by Dutch trawlers.

Archaeologists have known for some time now that our ancestors once lived on land now submerged beneath the waves. In 1931, a North Sea trawler hauled up an antler spear tip dating from 13,000 years ago. But there was little researchers could do – they couldn't excavate 40km (25 miles) off the Norfolk coast.

New technologies, however, are enabling today's archaeologists to explore this submerged landscape off Britain's coast as well as some in other oceans (see 'Lost lands around the world' on p40). Beneath the murky waters surrounding Britain, they have rediscovered hills, valleys, swamps and lakes that would have been known by our Mesolithic ancestors. This lost world is bigger than many modern European countries and would have supported a population of tens of thousands of people.

The sunken landscape is an archaeological site on a grand scale and after years of plotting the lie of the land, archaeologists are exploring specific locations in detail, hoping to find something that has so far eluded them: human remains.

DIGITAL EXPLORATION

The first signs of the scale of this lost world began to emerge in 1998, when Professor Bryony Coles, a wetland archaeologist at the University of Exeter, investigated the location of that North Sea spear tip. By using principles from glacial geology and measurements of sea level depth she drew some maps. She gave this submerged land a name after Dogger Bank, the region in the BBC *Shipping Forecast*. That name was Doggerland.

But in 2000, University of Birmingham archaeologists Professor Vince Gaffney and Dr Simon Fitch decided to see if they could build a more detailed picture of Doggerland and asked industry for help. Thanks to the oil, gas, aggregate and windfarm industries, the North Sea is one of the best-surveyed underwater regions in the world. Vast amounts of seismic data have been collected by ships towing receivers to map the sub-floor geology. All that Gaffney and Fitch needed to do was extract the relevant information from the data so that rather than revealing the geology deep beneath the surface, it plotted ancient landscapes hidden just beneath the sea floor (see 'Raising Britain's lost landscape' on p39).

Within weeks of being given a sample of cross-industry data by the company Petroleum Geo-Services, their hopes were confirmed: the ghost of an unknown river, whose bed now lay within the Dogger Bank, snaked in luminous green across their computer screens. Gaffney and Fitch had landed their 'Mars rover'. Unknown landscapes beckoned.

They acquired 23,000km^2 (14,200 square miles) of data, and charted former estuaries, hills and marshland across an area the size of Holland. They then tested the digital maps by 'ground truthing' with vibrocores, powerful drills that can withstand deep-sea pressures and retrieve columns of silt and gravel. Some 50km (31 miles) off the cost of Norfolk, where their data told them there was once a meandering river, up came a layer of peat. It contained hazel nuts, reeds, wood and beetles, which carbon dating told them were 8,000 years old – remnants of a world known to ancient hunters. "This is very significant," says Fitch, "and safer than sending down divers."

After mapping vast tracts of land, archaeologists were able to pinpoint locations where our ancestors are likely to have lived before investigating these in more detail using geophysics.

"We are looking for areas where the conditions would have been right for people to have lived there and for what they were doing in those environments to have been preserved," says Dr Richard Bates, a geophysicist at the University of St Andrews. "Geophysical studies can then scan large areas and pinpoint locations

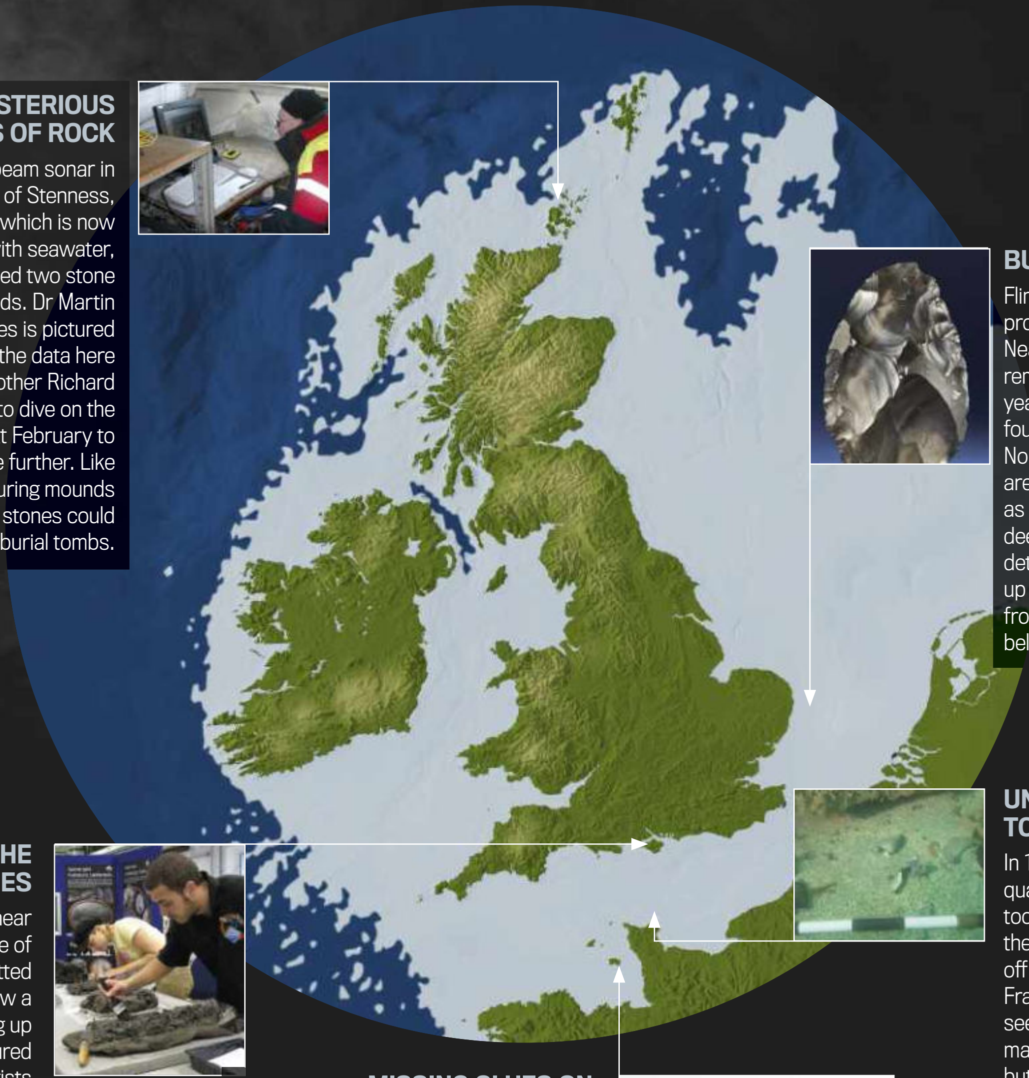
A cast of a child's footprint made at Borth, west Wales; it's thought that the children were tending animals around a waterhole

THE MYSTERIES OF DOGGERLAND

Five of the most intriguing questions posed by discoveries within Britain's lost land

KEY

⬜ Ancient landscape off Britain's coast



MYSTERIOUS PILES OF ROCK

Multibeam sonar in the Loch of Stenness, Orkney, which is now filled with seawater, identified two stone mounds. Dr Martin Bates is pictured studying the data here and his brother Richard plans to dive on the site next February to investigate further. Like neighbouring mounds inland, the stones could cover burial tombs.

BURIED TOO DEEP

Flint handaxes (pictured) probably made by Neanderthals and animal remains from 300,000 years ago have been found off the coast of Norfolk. Archaeologists are at a loss, however, as to how to study these deep North Sea sites in detail: the discoveries turn up among gravel dredged from up to 30m or more below stormy seas.

CASE OF THE MISSING HOMES

Mesolithic remains near Bouldnor on the Isle of Wight were first spotted by divers who saw a lobster burrowing up ancient flints. Pictured here, archaeologists work on the finds, which include hazelnuts and worked timbers, signs of fire and Britain's oldest piece of string, on what was dry land 8,000 years ago – but so far, no houses. What were people doing there?

MISSING CLUES ON A BIG GAME HUNT

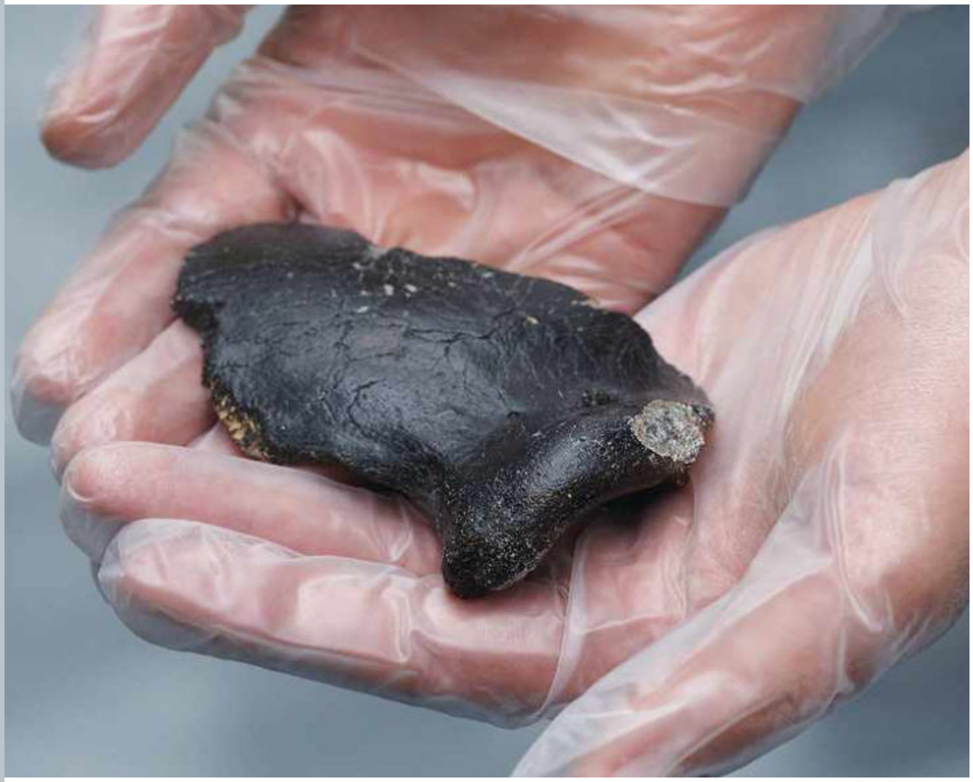
Excavations on the Jersey coast (pictured) found heaps of bones: it seemed Neanderthals had driven herds over a cliff and feasted on mammoth flesh 150,000 years ago. A new underwater survey, however, has revealed a now submerged valley, suggesting instead that the Neanderthals drove mammoths and rhinos to the cliff's foot. So the Neanderthals' modus operandi is far from clear.

UNEXPLAINED TOOL FACTORY

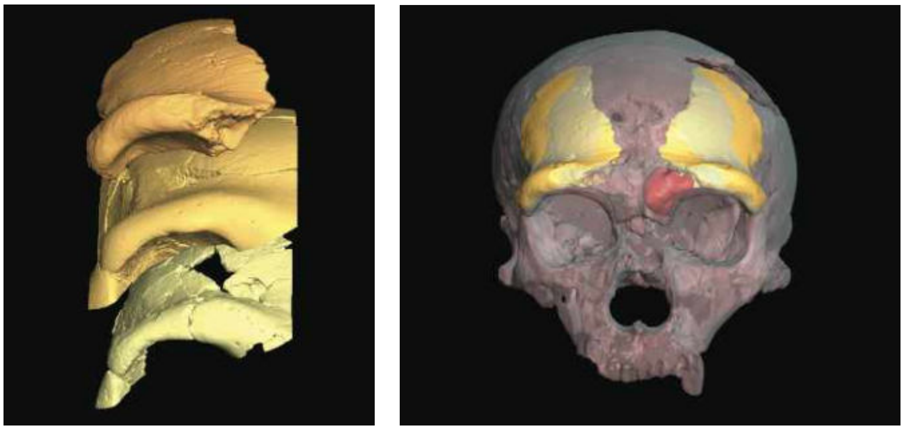
In 1970 divers found quantities of ancient flint tools (pictured) 20m below the sea east of Cherbourg, off the north coast of France. The artefacts seemed to be of a type made by Neanderthals, but this was not confirmed until further diving, excavation work and a seismic survey 10 years ago. Neanderthals had made the tools at the bottom of a cliff 70,000 years ago. Why they were there, however, is not yet known.

Key moments in Doggerland's past

850,000 years ago	50,000 years ago	32,000 years ago	8,100 years ago	5,500 years ago
Early humans (species unknown) first reach Doggerland, leaving artefacts on what is now the Norfolk coast.	Doggerland is home to Neanderthals, who live off large game like mammoths, rhinos and horses.	For Mesolithic hunters and fishers, Doggerland is an ideal place to live in northwest Europe.	A tsunami starts off the coast of Norway and destroys the remaining land of Doggerland, cutting Britain off from Europe.	The seas around Britain reach approximately their present level, though local flooding and erosion continue to the present day.



Above: found in material dredged up from the North Sea, this fragment of Neanderthal skull belonged to a young adult male 60,000 years ago. Below: the fragment is compared with other specimens (left) and mapped on to a full skull (right)



to send divers and ROVs [remotely operated underwater vehicles] down. It's like starting by finding a shovel in a haystack and then trying to find a needle on that shovel."

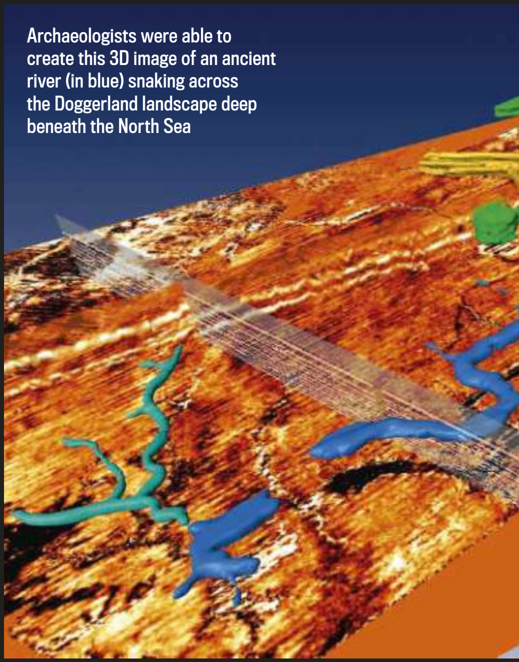
By studying these 'needles', the locations where our ancestors lived, it's hoped to piece together a picture of *how* they lived. At Orkney, Richard and his team modelled the sea floor and its layers below with multi-beam sonar, seismic profiling and magnetometers – which measure the strength of magnetic fields – as well as data from aerial photography and vibrocores. They found stone mounds in the Bay of Firth and in the tidal Loch of Stenness. The tallest of these sandstone structures stands at 4m and the widest is 40m in diameter.

"It's hard for us to explain these mounds using natural processes and they fit the right timescale for when we are pretty sure people were there," says Richard. "Quite what people were doing there we don't know. All we've got to go by are the later stone features on the land." Nearby at Maeshowe, Neolithic people built a stone mound and burial chambers. This mound is so significant it was declared part of a World Heritage Site in 1999.

In September, Richard and his team travelled to Orkney hoping to dive on the most recently discovered mounds – the ones on the bottom of the Loch of Stenness – to try to learn more about them. But bad weather meant they could only take core samples from the sediment around the stones. "We want to confirm that it would have been dry land at the time the stone was there – that's another piece of the puzzle as to whether they were created by humans or not," says Richard. He plans to return in February to dive in the loch.

Richard has also been working with his brother Martin at the opposite end of the British Isles off the coast of Jersey. There they are transforming our understanding of an iconic Neanderthal site. Excavations in the last century at La Cotte de St Brelade, a coastal cave, found astonishing quantities of mammoth and rhino bones at what, 150,000 years ago, would have been the foot of a tall cliff. It was argued that Neanderthals, whose bones have also been found, drove herds over the ravine.

RAISING BRITAIN'S LOST LANDSCAPE

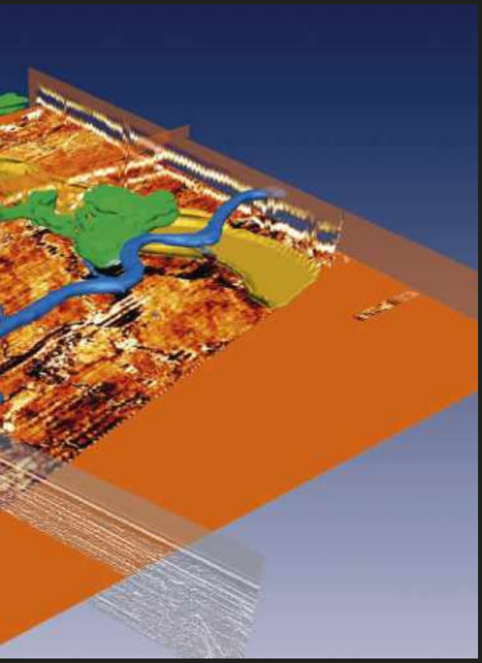


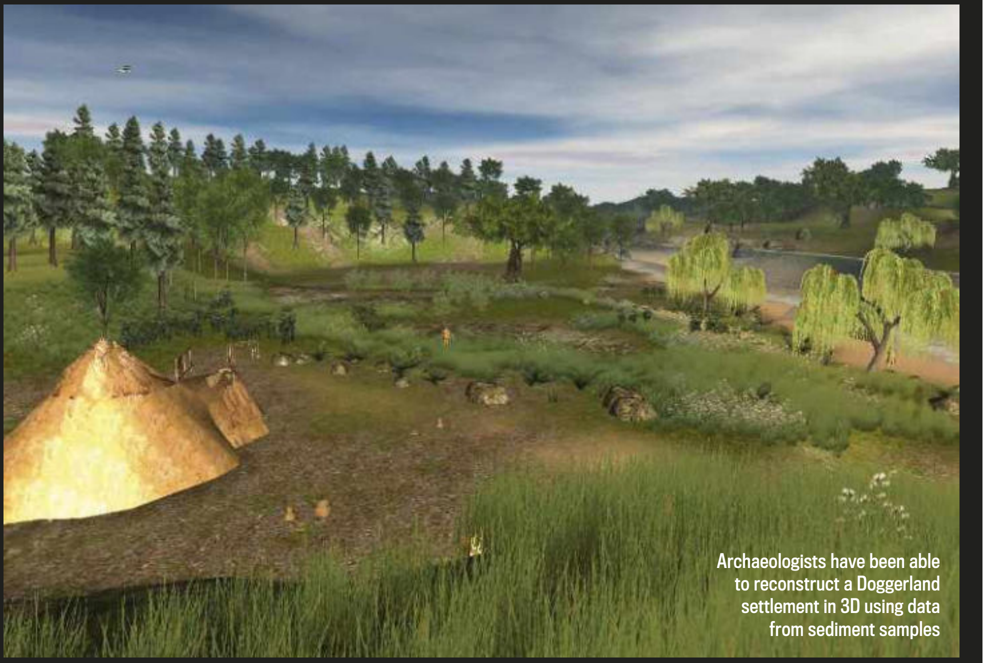
Archaeologists were able to create this 3D image of an ancient river (in blue) snaking across the Doggerland landscape deep beneath the North Sea

STEP 1:

Oil industry survey ships tow hydrophones across the North Sea, picking up sound waves bounced off sediment boundaries below the seafloor. The sediment layer positions can then be calculated from the time it takes the signal to return. The company Petroleum Geo-Services gave University

How archaeologists recreated the sunken world using data from the oil industry





Archaeologists have been able to reconstruct a Doggerland settlement in 3D using data from sediment samples

of Birmingham archaeologists unique access to this data. To map Doggerland's terrain, the archaeologists only used data on the shallow deposits of sediment. Even so, they needed 1,000 gigabytes of storage. It has allowed them to follow ancient coastlines, rivers and their tributaries in three dimensions.

STEP 2

To turn the images into real-world visualisations, the Birmingham archaeologists drew on knowledge of Mesolithic people. One study charted the return of vegetation in what is now the English Channel, as the Ice Age ended some 10,000 years ago. A cold, dry land indicated by birch, pine, oak and hazel pollen, ceded to warmer times with freshwater reed swamps and salt marshes. This was a rich world for the hunter-fishers, who left their traces in the form of charcoal and flint artefacts. Sediment samples from the North Sea have revealed 8,000-year-old plants, beetles and tidal muds.

"Archaeologists call this flooded land a bridge. No! It was the primary area of human habitation"

Professor Vince Gaffney, University of Birmingham archaeologist

Realising there had then been a vast, now submerged landscape beyond the cave, in summer 2011 the Bates brothers conducted a seismic survey of the sea floor. They found a network of ancient valleys with steep sides. It looks as if the Neanderthals may have been doing the opposite to what everyone had thought: they were driving the beasts up a valley, trapping them against the cliff – a more controlled, sophisticated form of hunting. "Now we need to get in the water, onto the sea floor. Are there any artefacts down there?" Richard wonders.

Although human remains have been found on the coast, none have been found out at sea. "Ultimately, we want to find remains of humans because it would prove this area was occupied beyond a shadow of a doubt," says Richard. "That would be just stunning. It would be amazing."

MISSING BODIES

The next task is to build a picture of how people lived in Doggerland. "Archaeologists call this flooded land a bridge", says Gaffney. "No! It was the primary area of human habitation." People would have gathered around the shores and estuaries to exploit the bountiful resources – isotope evidence from human bone excavated on land either side of the North Sea suggests a marine diet.

This region would have started to disappear when the ice began to

P42

PHOTO: DUTCH NATIONAL MUSEUM OF ANTIQUITIES, NORTH SEA PALAEOLANDSCAPE PROJECT/UNIVERSITY OF BIRMINGHAM, DR. EUGENE CH'NG/UNIVERSITY OF BIRMINGHAM, DR. JEAN-JACQUES HUBLIN X2

LOST LANDS AROUND THE WORLD

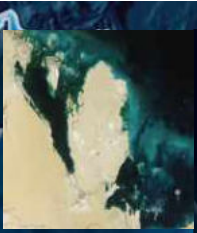
Submerged ancient landscapes are revealing how our ancestors lived

BLACK SEA: THE CASE OF THE ANCIENT FLOODS

The Black Sea (pictured), which is largely oxygen-free, is dubbed the world's largest underwater museum and is an ideal place for preserving ancient remains. Thus, reasoned a Canadian-American research team, it should be easy to test theories that propose two catastrophic inflows, with evidence of destroyed settlements. One is thought to have happened 14-17,000 years ago and have been fed by the Caspian Sea to the east, and the other let in the Mediterranean 7-8,000 years ago. Either of these might have inspired the Biblical flood story. With data gathered by seismic profiling, seafloor sampling and onshore studies, the scientists concluded that flooding had taken place twice and the event that occurred 7-8,000 years ago was gradual. But they found no evidence that anyone lived there at either time.

MEDITERRANEAN: GHOST VILLAGE

Archaeologists exploring offshore sand quarries and construction sites on the coast of Israel found dramatic evidence for sophisticated early farmers whose lands were flooded by rising seas. Their village at Atlit Yam dated to 8,500-9,200 years ago. It boasted deep stone wells, stone-built houses, ritual megaliths and a cemetery with the remains of 65 people (pictured) preserved beneath the Mediterranean. Finds of fish bones, seeds, wood and pollen indicate a lifestyle based on hunting, fishing and farming. More recent Neolithic remains, from around 7-8,000 years ago, are spread along the coast in an underwater zone 200m wide and 15km (9 miles) long.



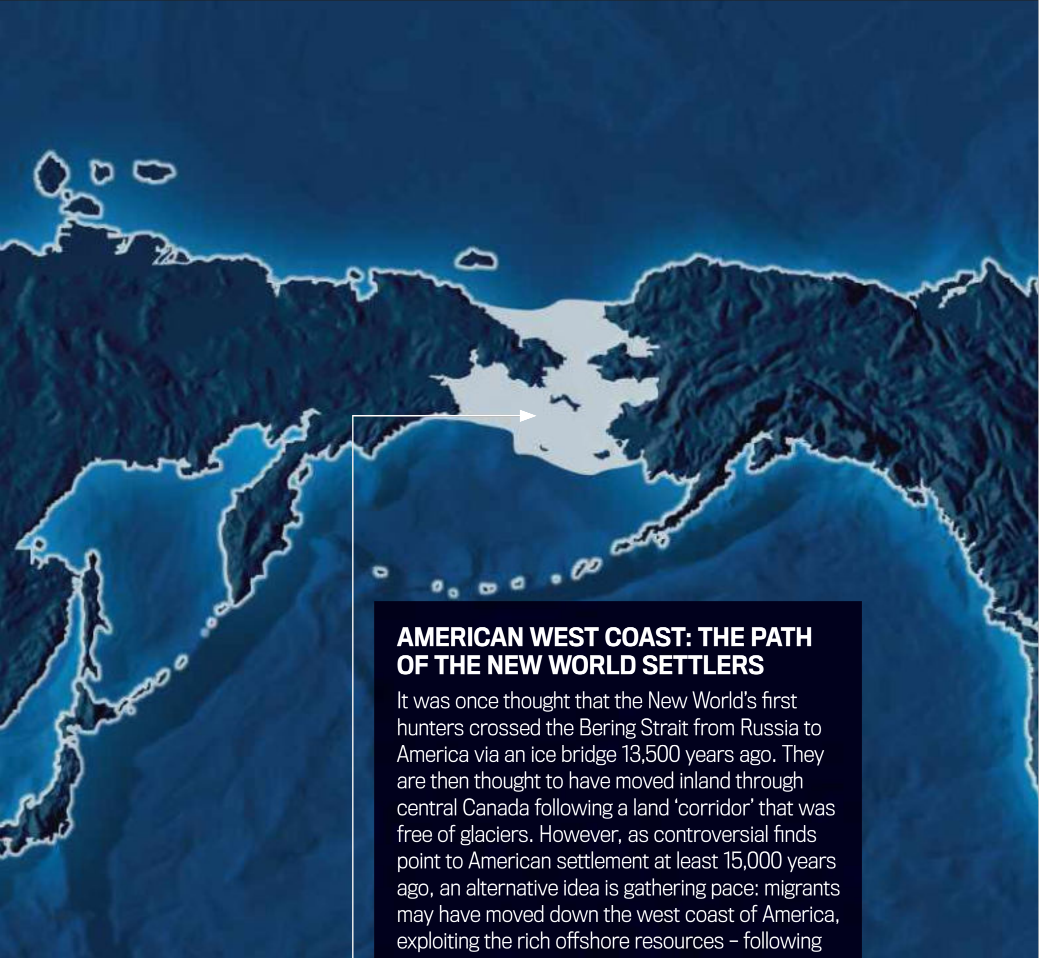
QATAR: DIVING FOR LOST LANDSCAPES

Large areas of land were submerged in what is now the Persian Gulf (pictured), as global sea levels rose with a warming climate 7,500-14,000 years ago. A major research project to investigate these former landscapes by the Qatar Museums Authority and the University of Birmingham, inspired by the mapping of Doggerland, is now in its fourth year. Oil companies have provided 4,000 square kilometres of high-resolution 3D seismic data, with results soon to be published. Geophysics surveys are planned for 2013 as well as diver inspections off Qatar's northwest coast, where fresh water aquifers suggest areas where prehistoric people might have lived.

SOUTH AFRICA: OFFSHORE CAVE HOMES

Some of the most spectacular finds relating to early modern humans are being made in coastal caves in South Africa. At Blombos Cave, simple art and artefacts like shell beads (pictured) have been found that are twice as old as similar examples created in Europe 40,000 years ago. However, no-one was more surprised than archaeologist Dr Bruno Werz, of the Southern African Institute of Maritime Archaeology, when he found a stone axe in Table Bay, out to sea off Cape Town, while excavating 17th Century shipwrecks. A further search produced rhino fossils and two more axes, which could be 300,000 to 1.4 million years old. Operation Zembe was launched in 2002 to find caves where early humans might have lived.

PHOTO: NASA X2, AKG-IMAGES X2, UNIVERSITY OF OREGON, CHRIS HENSHILWOOD, ISRAEL HERSHKOVITZ MAP: MARTIN SANDERS



AMERICAN WEST COAST: THE PATH OF THE NEW WORLD SETTLERS

It was once thought that the New World's first hunters crossed the Bering Strait from Russia to America via an ice bridge 13,500 years ago. They are then thought to have moved inland through central Canada following a land 'corridor' that was free of glaciers. However, as controversial finds point to American settlement at least 15,000 years ago, an alternative idea is gathering pace: migrants may have moved down the west coast of America, exploiting the rich offshore resources – following a 'kelp highway'. This would have been a quicker means of colonisation, explaining the earlier dates. The search is now on for submerged villages. Finds include a stone artefact (pictured) over 50m below the sea near the Queen Charlotte Islands in the north, and human remains on California's Channel Islands dating back to 13,000 years ago.

> **"It's likely that key events in early human history are linked to these lost worlds"**
>
> Professor Vince Gaffney, University of Birmingham

HUNT FOR ATLANTIS

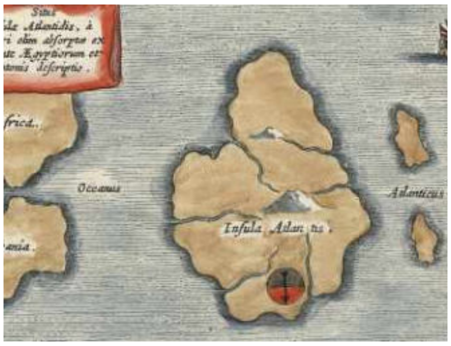
The search for the island that sank

Doggerland is often described as Europe's Atlantis. Though when Plato described 'an island larger than Libya and Asia combined' that vanished overnight midst earthquakes and floods, he almost certainly imagined waters warmer than the North Sea. But was his 350BC text pure fiction, or did it embody memories of a real event?

In 2009-10 American, Canadian and Spanish researchers used satellite photography and ground-penetrating radar to investigate remains said to be Atlantis in southern Spain. The search began after Dr Rainer Kühne argued that a site for Atlantis near Cadiz would fit Plato's story. A fellow German, Werner Wickboldt, claimed to have seen rectangular structures and concentric rings in satellite photographs in the Doña Ana Park, a huge swamp. But nothing was found in the investigation that matched predictions, and a British archaeologist commented that 'several leaps of faith' were required to accept the argument.

Plato's Atlantis idea has been kept alive by philosophers, satirists and fantasists, who have placed the lost civilisation at the North and South Poles and almost everywhere in between. There is perhaps just one archaeological theory that has any serious claim on the myth. This is that Atlantis was the small island of Thera (or Santorini), 100km (62 miles) from Crete. Thera was blown apart by a volcano in the Bronze Age around 1500BC, sending out a tsunami that devastated the coast of Crete. Crete was home to the advanced Minoan civilisation that was already in decline.

An artist's impression of Atlantis as it would have appeared in the area now occupied by the Doña Ana Park swamp


Situs Ile Atlantidis, à ri olim absorptae ex ... Aegyptiorum et ... descriptio.
frica
Oceanus
Insula Atlan tis
Atlanticus

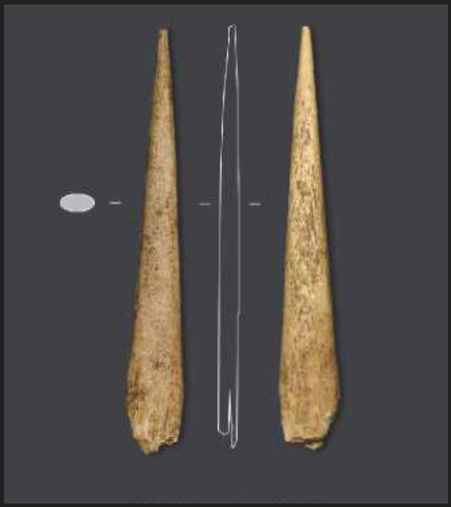
A 17th Century map of the lost land of Atlantis (middle) shown off the coast of Africa

THREE KEY ARTEFACTS

These discoveries have provided important insights into life in Doggerland

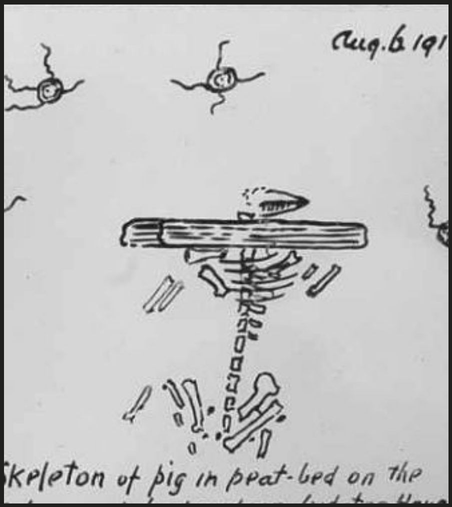
1. FLINT: 10,000-18,000 YEARS OLD

In 1981, a worked flint (pictured) was found in a core from the North Sea bed between Shetland and Norway, 17 years before Doggerland was described. When archaeologist Caroline Wickham-Jones at the University of Aberdeen saw it, she at first thought that someone must have dropped it overboard.



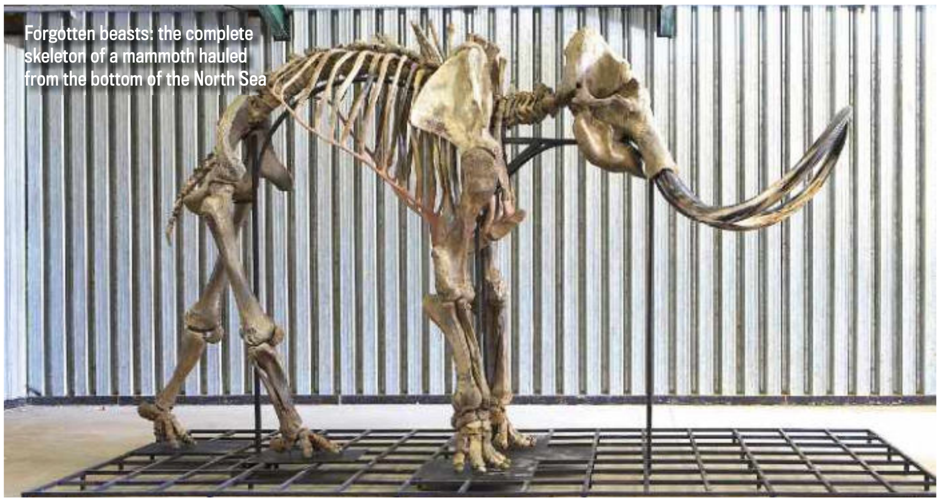
2. SPEAR TIP: 13,000-14,000 YEARS OLD

A spear tip carved from red deer antler was trawled from the North Sea off Norfolk in 1931. Similar points (pictured) have been excavated in Britain and on the continent, including one found among the foot bones of a complete elk skeleton near Blackpool, Lancashire.


Aug. 6 191
Skeleton of pig in peat-bed on the

3. HUNTED PIG: 6,300 YEARS OLD

The skeleton of a wild pig trapped by a log (drawing of find pictured) was found in a submerged forest at Lydstep, near Tenby, in 1917. Flint spear tips were embedded in its neck. In 2010, archaeologists identified the footprints of red deer and people, including children, nearby.



Forgotten beasts: the complete skeleton of a mammoth hauled from the bottom of the North Sea

PHOTO: CAROLINE WICKHAM-JONES, JOSÉ-MIGUEL TEJERO, TENBY MUSEUM AND ART GALLERY, HANS WILDSCHUT

melt some 10,000 years ago – a slow process. At one point, however, it was anything but calm. Around 8,100 years ago, a massive landslide off the coast of Norway threw up a tidal wave that rolled across the north Atlantic and down the North Sea. Hundreds of kilometres of shoreline along eastern Scotland and northeast England were hit by a tsunami. As it swept over the coastal forests and up the rivers, as many as 3,000 people may have died. When it was over, Britain was finally separated from the continent.

While remote sensing technology is lifting Doggerland from the seas, more revelations could come about through the falling cost of DNA sequencing. Traditionally, ancient ecologies are studied through preserved flora and fauna, from pollen and wood remains to mollusc shells and bones. Recovering these needs large samples, and their study is labour intensive and expensive. Ancient DNA can be sought in the vibrocore samples and its analysis is automated. Gaffney anticipates a time when all the genetic material in a sediment sample will be sequenced, whether from pollen, microbes or skin. “We’re on the verge of a revolution,” he says.

But even without the latest technology, we can all help bring this sunken world to life. In 2000, a walker named Mike Chambers found an ancient handaxe while exercising his dog on the Norfolk coast. In doing so he identified what has become one of the world’s most important early human sites. Our ancestors’ footprints are waiting to be discovered. ■

Find out more

http://bit.ly/U4kZAp
Professor Vince Gaffney explains his research on Doggerland

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MIKE PITTS is a writer and the editor of *British Archaeology* magazine

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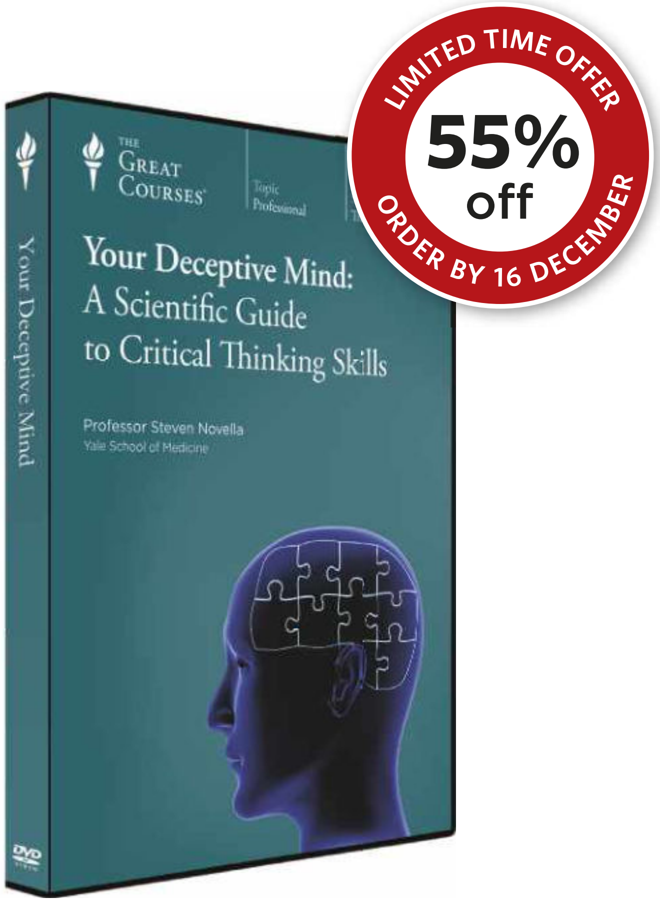

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THE STRANGE WORLD OF HALLUCINATIONS

From seeing things to hearing voices, hallucinations distort every one of our main senses. **Sam McNerney** explores our problems of perception

For more on hallucinations listen to *Hallucinations: Through The Doors Of Perception* on BBC iPlayer

ILLUSTRATOR: ANDY POTTS

THERE IS NO clear distinction between perceiving and hallucinating. What we call 'real' perception might just be your brain picking a hallucination that best aligns with reality. Spotting one is only easy when it's peculiar; the rest of the time you might be hoodwinked. For all you know, the image of a brain on the previous page might have been a hallucination. But what happens at the neurological level during a hallucination? What causes it? And what, exactly, counts as a hallucination?

Welcome to the strange science of hallucinations, where cognitive scientists use the latest in brain-scanning technology to pinpoint the causes and characteristics of these sometimes psychedelic occurrences. It's not an easy field to study: hallucinations can take place under so many different circumstances – sleep deprivation, migraines and neurological disorders to name but a few – that a simple one-size-fits-all explanation simply isn't possible.

Hallucination is often linked to psychosis. As famously depicted in the movie *A Beautiful Mind*, for instance, the mathematician John Nash suffered from delusions due to paranoid schizophrenia. But scores of mentally healthy individuals also experience unusual perceptions.

The word 'hallucination' was coined by medical writer Sir Thomas Browne in the 17th Century. Although instances are sprinkled throughout ancient and medieval texts, most cases went undiagnosed – in no small part due to medical ignorance: for centuries, dementia was the go-to explanation for a variety of brain disorders. Another reason for the lack of diagnosis is that people fear that visiting a doctor to describe their experiences would leave them with the unfortunate and inaccurate label of 'mentally ill'.

But while our understanding has come a long way since the field was established in the mid-19th Century, there are still many more questions than answers. "There are not only many definitions of hallucination, there is also no central way to hallucinate," says Dr Vaughan Bell of the Institute of Psychiatry at King's College London. "On top of that, hallucinations have a variety of causes." Here we explore how they can trick our five main senses, and how new research is shedding light on this curious corner of brain science.

ILLUSTRATOR: ANDY POTTS ICONS: INFOMEN

SMELL

Olfactory hallucinations can conjure up odours both delicious and disgusting

ALTHOUGH WE CAN hallucinate scents and odours, what we 'smell' varies. "People will report unpleasant smells like rotting and burning flesh," explains Dr Kathryn Eve Lewandowski, a clinical psychologist at McLean Hospital and Harvard Medical School. "These are recurring themes, but some patients describe more pleasant scents, like the smell of flowers."

Like the other four senses, olfactory (sense of smell) hallucinations are often linked to psychosis. According to one of Lewandowski's studies, about 15 per cent of patients with schizophrenia, schizoaffective and bipolar disorders experience non-existent odours. She also found that, like taste and touch, hallucinations of smell are linked to depression, a family history of mood disorders and psychotic illness manifesting at a relatively young age.

Hallucinating a smell isn't always bad, however. A survey of 51 people diagnosed with schizophrenia led by psychologists at Macquarie University in Sydney found that around 30 per cent of instances were pleasant experiences, and 19 per cent were neutral.

Phantosmia – literally, 'phantom smells' – is a condition in which olfactory hallucinations are the primary symptom. The exact cause is still unclear, but they're associated with a variety of psychological disorders, as well as damage or abnormalities in the olfactory system. These hallucinations also result from head injuries, brain tumours, strokes, migraines and temporal lobe seizures. Strangely, they're sometimes isolated to just one nostril, and in most cases fantastical smells will slowly disappear over time.

Sometimes pleasant, often foul, your brain can conjure phantom smells – their cause is still not fully understood

Over 2 million people in the UK experience visual hallucinations. You could be one of them without realising…

SIGHT

The most well-known of hallucinations, problems of visual perception are also the most common

ONE PARADOX OF visual hallucinations is that they occur in people who are going blind. About 10 per cent of those who experience visual hallucinations have a significant loss of vision as a result of eye disease or damage to the optic pathways of the brain's neural circuitry. Known as Charles Bonnet syndrome after the Swiss philosopher, this odd array of symptoms includes a variety of visual hallucinations.

"Almost all patients will see simple patterns," says clinical psychiatrist Dr Dominic ffytche of King's College London, who adds that about 40 per cent see small figures wearing elaborate costume or military uniform. "Another 40 per cent see disembodied faces usually described as grotesque, like a gargoyle." An estimated two-thirds of those with Charles Bonnet syndrome don't report their condition for fear of social rejection or an inaccurate diagnosis of being mentally unstable.

Stranger yet is Anton-Babinski syndrome. This is a result of damage to the visual processing centre of the brain and causes blind individuals to deny their blindness – that is, they're convinced that they can see.

Visual hallucinations also result from neurological disorders, including Alzheimer's, Parkinson's disease and the rarer Lewy Body dementia. Unlike Charles Bonnet syndrome, patients with these conditions have normal vision and the contents of their hallucinations aren't as bizarre. For example, instead of imaginary objects, they might hallucinate a real person who looks normal. Between 20 and 40 per cent of patients with schizophrenia experience visual hallucinations and other psychotic conditions can also produce them.

Altogether, around two million people in the UK experience visual hallucinations, but it's difficult to pinpoint this number because it doesn't take into account basic visual misperceptions like phosphenes – the spots you see after rubbing your eyes. A recent £1.9 million grant from the National Institute for Health Research will help Dr ffytche investigate visual hallucinations further.

Recreational drugs offer scientists an opportunity to study hallucinations at the neurological level. In the neuropsychopharmacology unit at Imperial College London, Dr Robin Carhart-Harris induces hallucinations in subjects using psilocybin – the active compound in magic mushrooms – and measures blood flow and activity in the cortex to produce images of the brain. "During visual hallucinations under psilocybin, the brain is less ordered and organised," he explains. "Individuals are more internally oriented and less goal oriented."

Exactly which parts of the brain are active is a bit of a mystery though. Carhart-Harris predicted that the visual cortex would be associated with visual hallucinations, but didn't find any supporting evidence and confesses that there's still little consensus on which brain regions are associated with them.

SOUND

People with certain neurological disorders suffer from auditory verbal hallucinations, while many of us also hear voices

FAMOUS EXAMPLES OF audio hallucinations appear throughout history: the German composer Robert Schumann was said to have experienced musical hallucinations and Joan of Arc claimed that the voices of saints sent from God guided her. Psychiatrist Vaughan Bell suggests that many religious revelations were simply problems of auditory perception.

So what happens in the brain during these hallucinations? It depends on both the person and what they're hallucinating. One approach is to study the most common type: auditory verbal hallucinations (AVHs). "There are many brain areas involved in AVHs," explains psychiatrist Dr Renaud Jardri, who studies the phenomenon in patients with schizophrenia. "We need to think in terms of networks, not just isolated regions."

AVHs are a hallmark of schizophrenia, with about 70 per cent of patients experiencing them. They also occur in people with other neurological disorders – including Parkinson's disease, epilepsy and dementia – and even in healthy individuals.

The neurological differences of AVHs in those with a mental condition and people without a disorder are unknown, but based on a study led by clinical psychologist Dr Frank Larøi of the University of Liège in Belgium, the same brain regions might be involved. However, the differences are clear to the person experiencing such a hallucination: healthy individuals live normal lives by being able to control their 'voices', whereas patients react with stress and anxiety because the hallucinations significantly disrupt everyday life.

What's not known is the number of normal people who experience audio hallucinations, and experimental methods make it challenging to get a precise answer. The frequency, duration and intensity of audio hallucinations can also vary greatly, so it's difficult to define what 'counts' as a hallucination. Indeed, one study by clinical psychologist Vanessa Beavan of the Australian College of Applied Psychology puts the percentage of people experiencing them anywhere between 0.6 and 84 per cent.

Whether there's a difference between patients and non-patients at the developmental level is also unclear. Research suggests that healthy people develop auditory verbal hallucinations in their early teens, whereas those with psychological problems will often experience their first voice around the age of 20. "It's not unusual for non-patients to have a history of childhood trauma or a family history of psychological disorders," says Frank Larøi, who cautions that more research is needed.

The good news is that these hallucinations are now receiving more attention. They're being studied across Europe in non-clinical groups as well as in patients: an international consortium met in London last year, and a team at Durham University recently launched a project to study audio hallucinations, called 'Hearing the Voice'.

One of the most common types of hallucination, hearing voices is a symptom associated with many neurological problems

ILLUSTRATOR: ANDY POTTS. ICONS: INFOMEN

Taste something coppery? You could be experiencing one of the most uncommon forms of hallucination

TASTE

Unusual and uncommon, phantom tastes can have many causes

WHAT DOES A gustatory, or taste, hallucination involve? "They are the perception of taste in the absence of external stimuli and usually involve a metallic or coppery flavour," describes clinical psychologist Dr Kathryn Eve Lewandowski. She led a 2009 study examining the prevalence of these hallucinations in patients with schizophrenia, schizoaffective disorder and bipolar disorder.

The least common kind of cognitive misfiring, research on the psychological and neurological underpinnings of taste hallucinations is so limited that scientists still hesitate to draw definite conclusions.

Lewandowski and her colleagues found that about four per cent of patients experienced them. They are also linked to temporal lobe epilepsy, but it's not unusual for them to be triggered by brain tumours, various psychotic disorders and drug abuse.

With this type of hallucination being so mysterious, it's unclear what proportion of the population experiences them. But a survey conducted in 2000 by medical epidemiologist Maurice Ohayon of Stanford University in California – involving over 13,000 non-institutionalised individuals from the UK, Germany and Italy – provides a hint. Ohayon found that around 1 per cent of them reported experiencing hallucinations of taste at least once a week. These people were linked with alcohol, drugs, depression and psychosis.

TOUCH

Tactile hallucinations are the most enigmatic of neural illusions

MISPERCEPTIONS OF TOUCH are difficult to define. If hallucination is perception without external stimuli, is an itch a hallucination? That question was posed in 1982 by psychiatrist German Berrios of Cambridge University, who theorised that tactile hallucinations are fundamentally different from those occurring in the other senses.

Research on tactile hallucinations is sparse and its origins date back to the 19th Century, when French psychiatrist Jean-Étienne Dominique Esquirol reported several cases. According to clinical psychologist Dr Kathryn Eve Lewandowski, at least we now know more about how they feel. "Patients with psychotic disorders experience tactile hallucinations in the form of crawling or burning sensations," she says. "Sometimes they have feelings of electricity or a sense that their organs have been rearranged."

Such extreme hallucinations are also felt in some forms of psychosis, such as Ekbom syndrome. "Patients usually develop the strong delusional belief that they are infested with parasites," says Dr Renaud Jardri. These dramatic and disturbing hallucinations are linked to brain injury and dementia, and are also common side effects for people who abuse cocaine, amphetamines and crystal meth.

It's not known which regions of the brain are active during tactile hallucinations, but it's possible that the same cognitive mechanisms involved in a phantom touch are also active in a real touch. If true, tactile hallucinations might be due to crossed wires in the brain as perceptual information from the senses gets mixed up. Understanding hallucinations at the neurological level will not only help patients deal with problems of perception, but also unravel these strange phenomena in healthy people. ■

SAM MCNERNEY is a science writer and runs the blog *Moments Of Genius* at bigthink.com

On 15 October, Radio 4 broadcast *Hallucinations: Through The Doors Of Perception.* Catch it on BBC iPlayer at www.bbc.co.uk/iplayer/radio

Dara O Briain

Comedian and TV science presenter

By Andy Ridgway

The *Mock The Week* star discusses his new science series, disturbing theories, and his eureka moment

What's the idea behind the new show?
We'll pick a topic in each episode and go into the leading edge on it – we'll have some senior scientists with us talking about the most exciting happenings. The show will look at the more controversial parts of the subject and there will also be experiments that we do in the studio.

One of the first programmes looks at Einstein. Is he your science hero or is there someone you hold in higher esteem?
No, it's Einstein for me. My personal experience with him can be traced to a shed in a garden 20 years ago. I used to study at night and I was in this room of my dad's that was basically a shed that had been turned into an office. I took it over to study for my finals and I remember the light bulb-above-head moment when I understood what Einstein was doing in general relativity: what he had taken and what he had replaced it with. It was the shift from 'it's about matter' to 'it's about the space'.

Is it hard to pitch a science TV programme at the right level?
Inevitably it's a huge debate – how much knowledge can we presume and do we have to start from zero every time? It's a problem when people tune in to a show and say 'I know this'. You feel like asking them to switch on after 20 minutes – the first 20 minutes being for people who don't already know. It's frustrating because you don't have to do it in sport. You don't have to say 'Right – this is the ball, there are two teams of 11 and...' Then again, I need to be reminded of the evolution of a star and things like that a million times!

What inspired you to study maths and theoretical physics at university?
I was 14 and it seemed full of great, exciting questions, space-time, fabulous curved diagrams, and things erupting and things collapsing to a point. Plus I like maths – it's a guilty secret.

Is there a scientific theory where you've thought, 'They're surely making this up...'
All the untestable theories are the ones people recoil slightly from. Or ones like string theory. You can say 'we'll never know whether there are strings, but it just kind of works'. There are theories that seem to come out of mathematics, but appear to have no physical meaning other than that. They're the ones that wreck people's heads! Theoretical physics teaches you to break a problem down and find a mathematical way of solving it. But at some point in the middle of all that you are not doing physics, you are just doing maths. When you put the physics back in at the end it can lead to some quite disturbing results. Quantum theory is disturbing, but it ended up being the most accurate theory of all in physics.

Has your scientific knowledge ever led you to veto a joke?
I must have irritated so many people on *Mock The Week*. I remember Hugh Dennis talking about the Large Hadron Collider and he said 'The hadron's a particle'. I corrected him by saying 'It's a *class* of particle'. And then you get a withering look for ruining the timing of a joke.

Is there a science to being funny?
No, you can only analyse it retrospectively. The rule of three is the only one you can really use as a writing tool. First man went to a bar, second man went to a bar, third man went to a bar... that's a funny one. It's not a proper law though. I think comedy has to surprise you. Even when you're writing you have to surprise yourself.

Did you think the 'neutrinos are faster than light' story was rubbish from the start?
I kind of presumed it would be settled the way it was. But it was great to see it being discussed. It's only irritating if people go 'Raa raa raa, Einstein was wrong!' People said if we didn't find the Higgs then that would also have been interesting. It would've been, but not for the punters. Punters go 'No that's a failure. Clearly the entire thing was a disaster!' So the fact that people jump on things and say there has to be a correct answer to this question is frustrating. ■

PHOTO: CAMERAPRESS

DARA O BRIAIN ON...

➔ ...multiple universes

"The notion that this conversation is also taking place in another region of the Universe or a completely separate universe but I am interviewing you... or that we're both upside down and we're both coloured purple seems too desperately close to the *Simpsons* episode where the toaster becomes a time machine."

➔ ...maths and comedy

"The process of making connections between things in comedy is not a lot different to solving problems in maths. It comes from a similar part of the brain. A lot of comedy is spotting the nature of one thing and comparing it to the nature of another thing. 'Hey, have you ever noticed that this is a bit like this?' That's what all mathematics is."

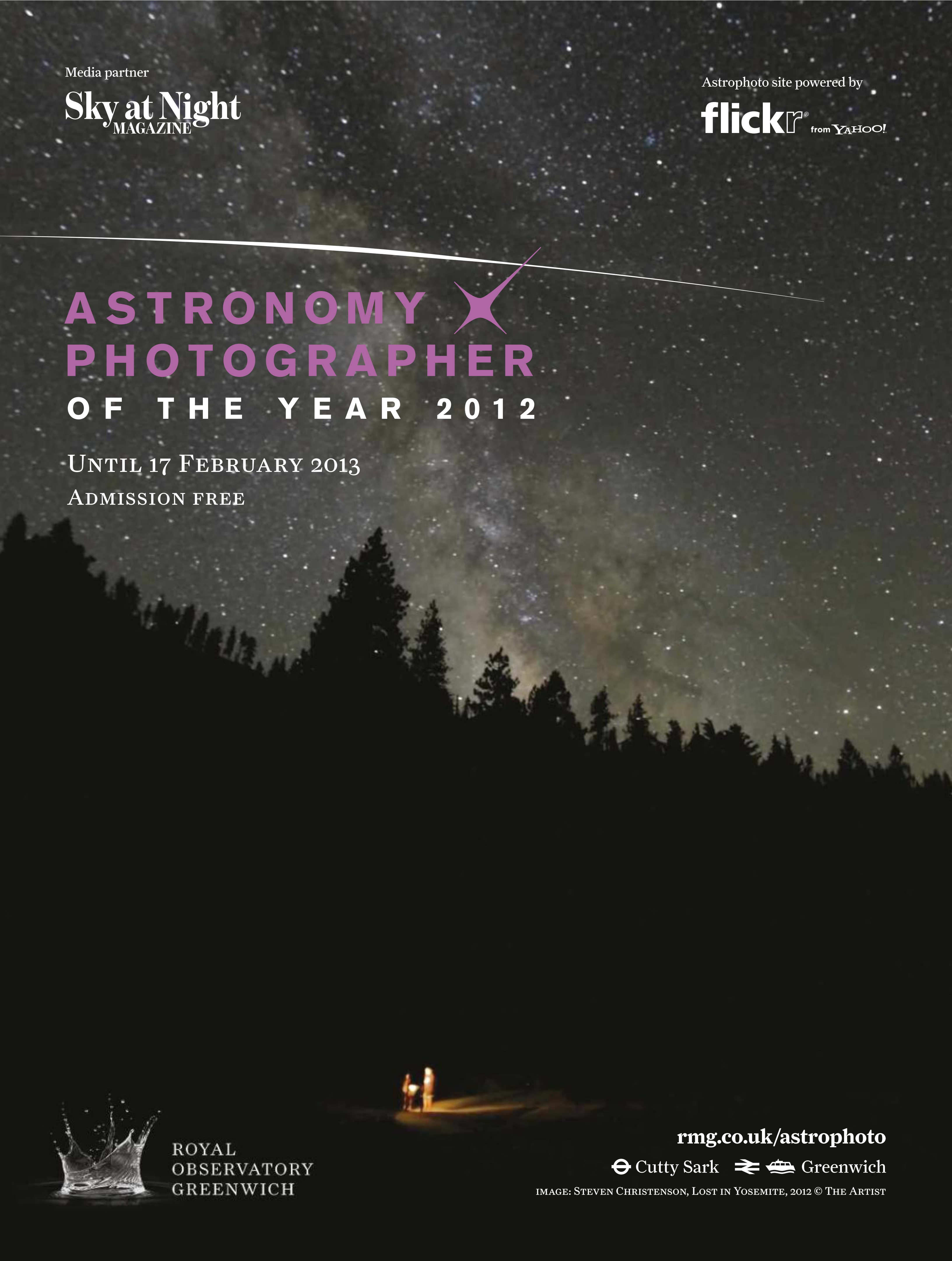
➔ ...taking a quantum physics exam on caffeine tablets

"I learned one very interesting physiological fact: caffeine tablets will help you dig a road, but they are not good for abstract thought. I remember my brain being asleep but my body being awake. And God love 'em, the examiners must have pieced together enough to get me through when they were marking. But it didn't deserve it."

BBC TWO

Dara O Briain's new science show will be screened on BBC Two. The first episode in this six-part series is broadcast in November. Turn to p103 for a preview.

“My personal experience with Einstein can be traced to a shed in a garden 20 years ago”



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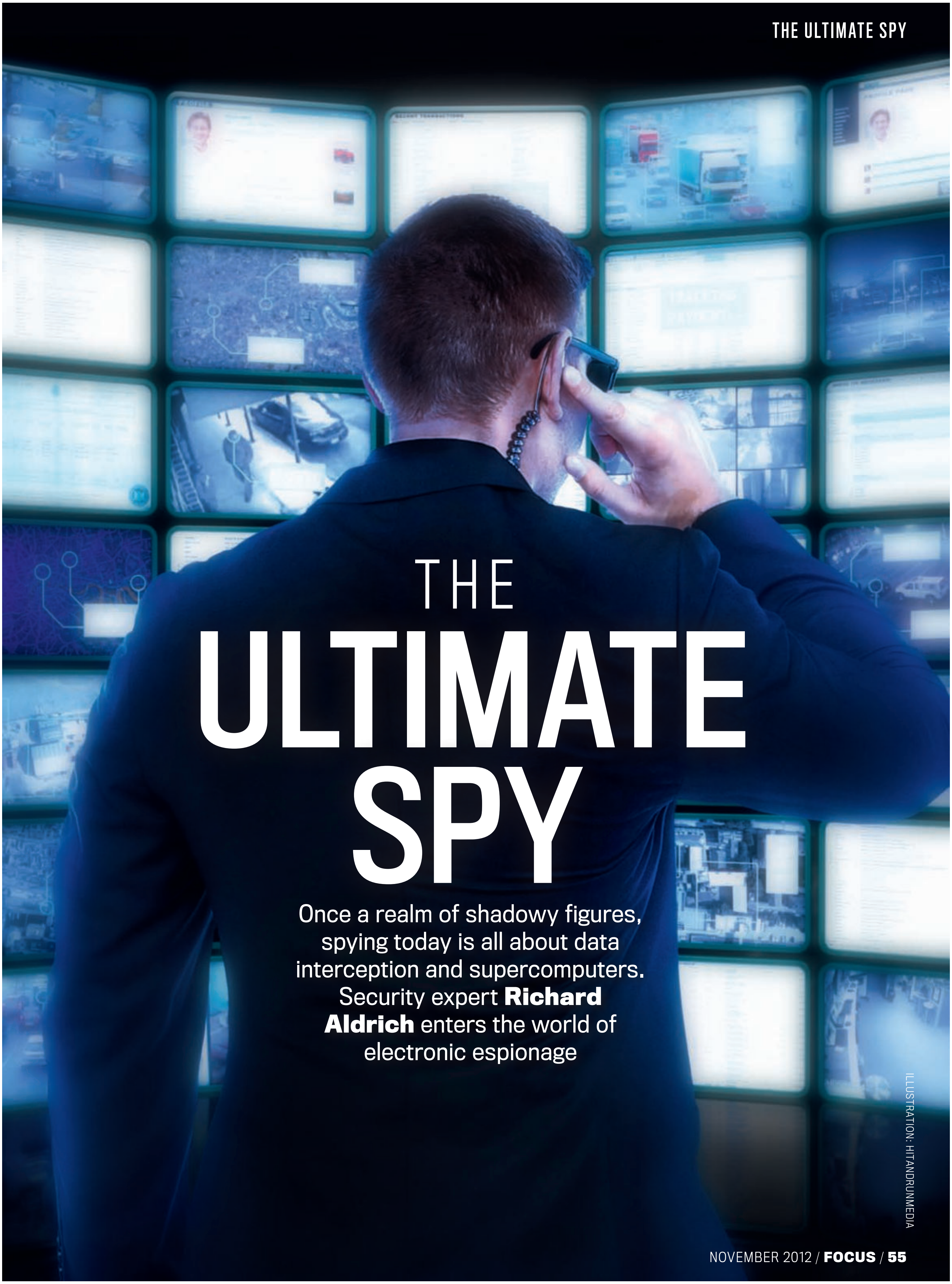


THE ULTIMATE SPY

Once a realm of shadowy figures, spying today is all about data interception and supercomputers. Security expert **Richard Aldrich** enters the world of electronic espionage

ILLUSTRATION: HITANDRUNMEDIA

FORGET JAMES BOND and Jason Bourne. The secret agencies featured in the movies – MI6 and the CIA – aren't as important as they seem. Instead, the real leviathans of the intelligence community have always been the technical agencies that spy with science.

Next year one of the world's largest spy centres will be completed. Mostly buried under the Utah desert, the complex will be a vast data silo covering an area almost 100,000m^2 in size and will store an unimaginable amount of electronic information. The site was chosen for its access to power grids that will meet the secret facility's enormous electricity demands. This is thought to include running a D-Wave quantum computer capable of doing calculations that would take millions of years on a desktop machine (see p29).

Known simply as the Utah Data Center, the underground complex is being built for the National Security Agency (NSA) – America's most secret intelligence organisation. It absorbs much of the gargantuan intelligence budget, most of which is spent on computers and spy satellites. The new $2 billion data silo is part of the 'Comprehensive National Cybersecurity Initiative', whose overt purpose is to provide the Department of Homeland Security with technical support and watch for cyber threats. But leading intelligence experts note that over the next two decades, the NSA is planning to expand its secure facilities by more than 500,000m^2 – the size of Vatican City.

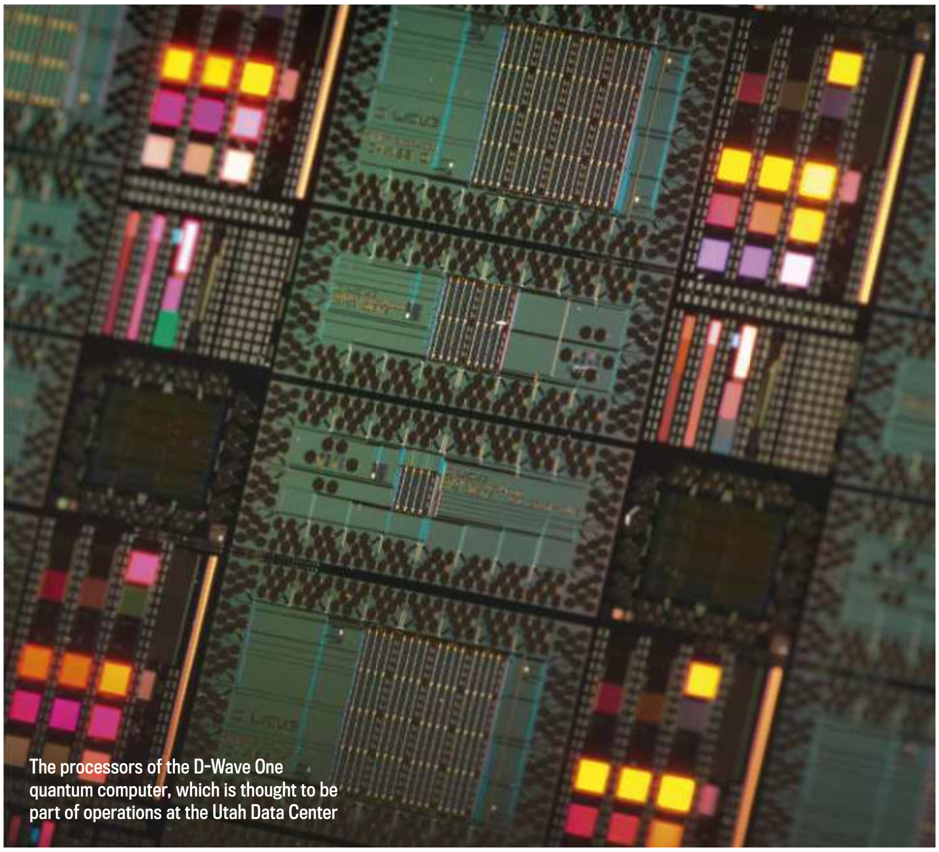
So what is all this space for? The answer is simple: to capture all of human activity. As one senior intelligence official tells *Focus*: "We know things about people that they don't even know themselves." Inspired by Google's data centres, which record our online activity through internet searches, the NSA realised it could pull together other kinds of ephemeral electronic information to create the virtual profiles of tens of thousands of people. "What they had, in effect, was a warehouse full of people's brain activity," says the intelligence official.

"We know things about people that they don't even know themselves"

Senior intelligence official

Spy agencies increasingly talk about the 'electronic exhaust fumes of our lives'. Every few minutes we emit some digital trace of our activity in the form of an email, SMS, phone call or credit card purchase. And although we regard such personal information as confidential, it's actually quite boring – and certainly not especially secret. Nonetheless, agencies can extract high-grade intelligence from our mundane details, which can involve breaking encryption (see right). And what intelligence agencies now do with our data marks a paradigm shift in the nature of surveillance on domestic citizens.

Until recently, agencies mostly performed 'retail surveillance' that required warrants or court permissions to observe individuals or small groups. But silos like the Utah Data Center make it easier to conduct 'wholesale surveillance' – trawling data from large groups using algorithms to search for patterns in the vast amounts of personal data. Since it's mostly done by machines, this process is sometimes called robotic spying, something made easier thanks to powerful supercomputers that crunch through complex input – including text, images and videos – to detect useful information.



The processors of the D-Wave One quantum computer, which is thought to be part of operations at the Utah Data Center

PHOTO: DWAVE, ALAMY

DIGITAL DOUGHNUT

The NSA's UK equivalent is GCHQ, the Government Communications Headquarters. GCHQ is the successor to the famous World War II code-breaking centre Bletchley Park. As well as cryptography, this secret agency also protects Britain's electronic infrastructure and has a new unit that can conduct cyber warfare on the internet. In

6,000

staff work at GCHQ. Numbers fell to 4,000 in the mid-1990s but the threat of terrorist attacks and cyber war means more employees are now needed

ENCRYPTION: CREATING THE UNBREAKABLE CODE

What is encryption?

Encryption converts readable information such as text into apparent nonsense. This process is controlled by a 'cipher', an algorithm that makes this information unintelligible (encryption) or readable (decryption). If you used the surname 'Smith' as a password and represented each letter as two digits, for example, you'd end up with 1913092008. If the cipher – converting name to number – and the 'key' (A=01… Z=26) were revealed, this simple encryption would be easy to break. Modern encryption methods are incredibly complex, generating apparent nonsense that can only be read by machines. Cryptography or 'secret writing' is the study and practice of encryption techniques, while the combination of a cipher and its key is popularly called a 'secret code'.

How do computers encrypt information?

Machines use a key consisting of bits (0s and 1s). In modern encryption, the size of the key can be any multiple of 32 bits and computers can try to break a cipher through a trial-and-error combination of keys. Encryption experts used to think that a key of 128 bits was strong enough to prevent a code from being broken by this brute force approach – trying all possible combinations would take 500 years – but with quantum computing just around the corner, cryptographers now agree that a key of 256 bits would give a greater margin of safety. Such strong encryption offers an exponential increase in security: cracking a 256-bit code using a modern machine would probably take about a billion years.

How is encryption used?

During World War II, Britain's code-breaking centre at Bletchley Park created 'Colossus', the first programmable computer. It was used to break ciphers such as Germany's famous Enigma machine. Publicly available encryption is now widely used in everything from banking transactions to mobile phone calls, which means authorities can only read information by asking a telecoms company for the key to a cipher.

In computing, shared memory enables multi-core machines to process data efficiently. The world's largest shared-memory system is the US 'Blacklight' supercomputer, which boasts 512 eight-core processors. But the facilities run by secret agencies are already said to make Blacklight look like a desktop PC.

The headquarters of GCHQ in Cheltenham. Known as 'the doughnut', it houses supercomputers underneath

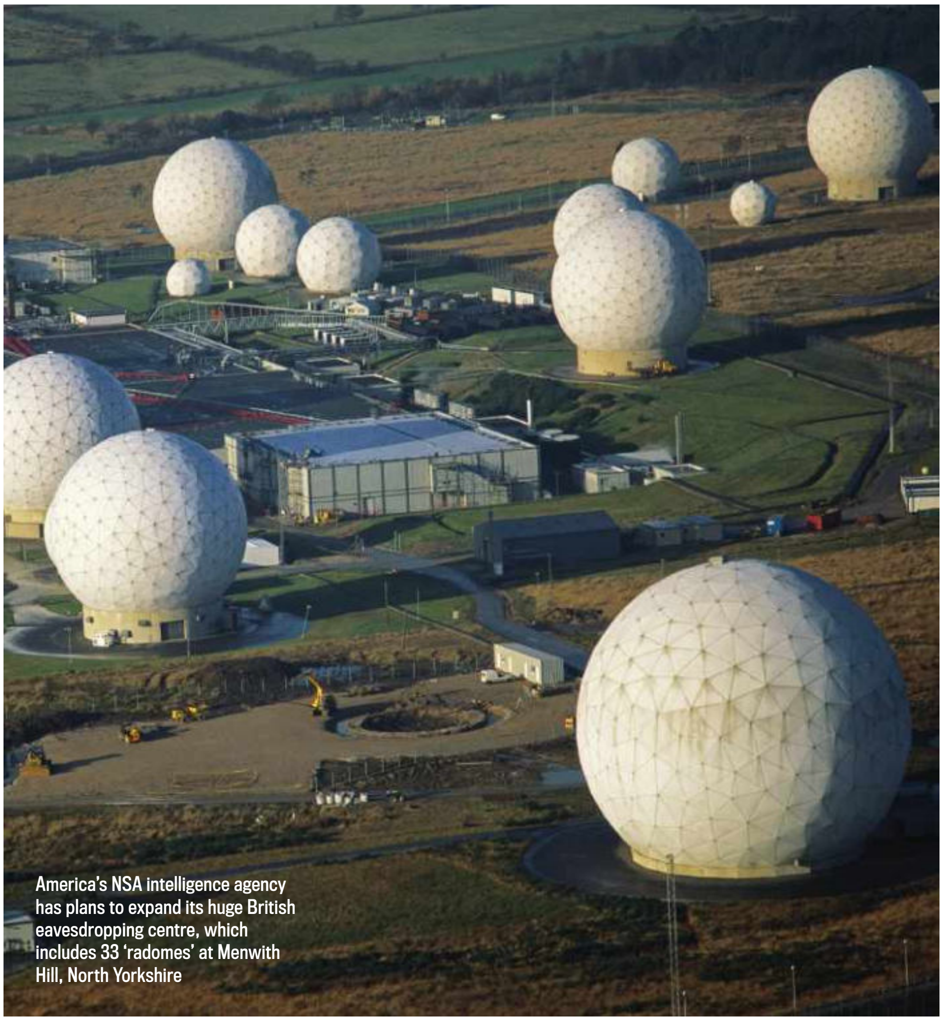
2003, GCHQ moved to an iconic new building in Cheltenham, nicknamed 'the doughnut'.

GCHQ's most important section – its brain – is hidden away in the basement: deep below the offices of its analysts and linguists are huge computer halls. The exact size and speed of its machines are secret, but it's rumoured that some store 25 petabytes (25 million gigabytes) of data and are equipped with over 20,000 CPU cores for rapid parallel processing. Such powerful computers are required for only a few specialist scientific tasks: simulating complex weather systems, mapping the human genome, designing nuclear weapons and, of course, cryptography. GCHQ is not a data silo, however, so is Britain building a complex like the one in Utah?

It turns out they've already tried. In 2008, the Home Office unveiled plans for a data silo, arguing that UK security agencies were being left behind by computer-literate terrorists and cyber criminals. Supposedly, the project was scrapped due to opposition from civil liberty and privacy campaigners.

Leaked documents reveal, however, that its biggest opponents came from within government. Britain's landscape of secret projects is littered with failures and runaway costs. In the 1980s, for example, GCHQ tried to follow the NSA into space with its own spy satellite programme, codenamed Zircon, which was shelved due to cost. The UK data silo was projected at £12 billion and – knowing that government IT projects can overspend – the Treasury applied the brakes.

Telecoms companies and internet service providers objected to the data silo too, claiming to be concerned about privacy. What they would have been more anxious about is commercial confidentiality – their key customers are businesses that set great store by commercial confidence. Documents recently released in the UK National Archives reveal the Bank of England's dismay when it first discovered GCHQ was reading financial communications.



America's NSA intelligence agency has plans to expand its huge British eavesdropping centre, which includes 33 'radomes' at Menwith Hill, North Yorkshire

PHOTO: CORBIS X2

"Trying to produce intelligence in this new environment is like trying to pour a glass of water with a fire hose"

Intelligence operative

Some experts believe the NSA and GCHQ are also planning to break the Advanced Encryption Standard, which protects transactions, financial activities and corporate email. With commercial espionage more prevalent than ever, some businesses fear that supercomputers and vast storage capabilities will mean the end of business privacy.

ROBOTIC DATA MINING

The centralised data silo may have been abandoned, but British authorities still have a plan 'B' for widening surveillance: a law that requires telecoms and internet companies to store the communications themselves – data that the government could then access on demand. These proposed legal provisions are known as the Communications Data Bill.

Some privacy campaigners prefer this option because it seems to provide safeguards. First, communications aren't stored by the government, which has a notoriously poor record of protecting data. In 2007, for instance, Her Majesty's Revenue and Customs admitted to losing the child benefit records of 25 million people. Second, and more importantly, data has to be requested piece by piece – an approach that appears to permit only 'retail surveillance' of individuals, not data-mining by robotic spies using algorithms.

But the Communications Data Bill could also enable robotic spying by the back door. It allows the authorities to ask service providers to undertake 'filtering' – essentially an algorithmic search of data – on the government's behalf. The legislation wouldn't cover the content of communications, only its context: a descriptive record of who phoned whom, when and where, or which websites were visited. But it's unclear how descriptive data in communications such as emails – which often remain unencrypted – could

SELF-SURVEILLANCE

Intelligence officers often joke that Facebook will put them out of business. How can they find work spying on people when we're broadcasting our own activities and watching each other? Social scientists point out that we now mostly spy on ourselves, and that the big issues in surveillance aren't about security and privacy, but our desire for convenience – made easier by the internet, mobiles and portable technology. This trend is accelerating – smartphones can map your location and plan out your driving route, while wearable devices like Fitbit measure sleep patterns and watch your weight.

But the distinction between public and private surveillance is also important. People seem happy for Tesco to track their shopping habits, but they're less comfortable when such data is in the hands of the Home Office. As a result, the focus of government surveillance is shifting. The challenge for the NSA and GCHQ is how to detect important information in our deluge of digital data.

Within a decade, the computer-brain interface – whereby we're directly controlling electronics with our minds – could be a reality and the pace of self-watching will accelerate again. Today, most of the world's digital data is no longer about state secrets, but about people – a generation that discloses every aspect of their lives. The end result could be a more a transparent society in which everything and everyone is recorded.

be analysed without also revealing its contents.

Services such as Gmail and Hotmail store messages on data servers based abroad – and hence not subject to UK laws – so these communications are tracked through 'deep packet inspection', the process of peeking inside a packet of data as it passes an inspection point on a computer network. This enables internet providers to check for viruses, spam, illicit peer-to-peer file sharing and unwanted intrusions. But deep packet inspection also allows censorship and eavesdropping.

2.5 BILLION communications, known as 'intercept events', are collected by the NSA every day and stored in over a hundred databases around the US.

Intelligence chiefs are sensitive about suggestions that they're creating an Orwellian world without personal privacy, countering that the current rise of a surveillance society is due to our own activities – a cultural change driven by technology (see 'Self-surveillance', above).

A world in which everyone shares personal information actually presents secret agencies with an enormous headache. We already send 2,000,000 emails a second – a digital tsunami – and as one intelligence operative tells *Focus*, "Trying to produce intelligence in this new environment is like trying to pour a glass of water with a fire hose." Even silos like the Utah Data Center aren't big enough to hold this information – much less make sense of it all.

Ironically then, citizens may eventually defeat government surveillance by creating oceans of electronic data that are too vast for spies to analyse. ■

PROF RICHARD ALDRICH is the author of *GCHQ: The Uncensored Story Of Britain's Most Secret Intelligence Agency*

Find out more

www.bbc.co.uk/programmes/b00rmssw
Listen to the BBC Radio 4 programme *GCHQ: Cracking The Code*

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Now, not only does a Box Design system cost less than traditional hi-fi equipment and fit within any room of your house, it also sounds first-class and offers features usually only associated with full-size, high-end hi-fi separates.

DOCK BOX S DIGITAL

This is the latest addition to Pro-Ject's popular range of iPod® and iPad® docking stations. The Dock Box S Digital has a small, stylish and well-built casing that houses a special Apple-authorised connector that is designed to extract your played music digitally.

That means the digital conversion can be done in the dock itself, allowing for a higher quality audio output that is well at home in any hi-fi system. The latest dock also offers complete control of your iPod library via the supplied remote control, and a USB port on the back allows users to connect to iTunes without undocking a device.

Docks from £130

STREAM BOX DS NET

The Pro-Ject Stream Box DS net is a high-specification music client that is designed to playback your entire digital music library in a convenient and great-sounding way.

By utilising a chip-set normally associated with products at a far higher price-point, Pro-Ject has produced a highly musical device that will play all of your digital music sources. Whether you want to play from an iPod, listen to internet radio, link with your NAS drive, or unlock the potential of your HD music stored on a hard drive, the Stream Box DS can help you.

The inclusion of a remote and a large high-visibility screen makes navigation and playback easy, but the recent addition of a free Apple and Android control app makes using the Stream Box an absolute joy.

Streamers from £699

CD BOX DS

The CD Box DS is a high-end CD Player that punches well above its weight. A premium specification servo system that is dedicated to producing the finest audio performance is used to make the CD Box DS an essential consideration for anyone looking to keep their CD library alive and well.

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A highly respected and truly enjoyable entry-level headphone pre-amplifier, the Head Box S allows you to enjoy your music in the comfort and privacy of your own headphones. The lifelike sound is produced by the high quality amplifier modules that are used, and the volume is controlled via the over-sized control on the front panel.

Headphone Pre-Amplifiers from £120

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The name Sansui literally means ‘mountain and water’, and it is the term used to describe an exquisite form of ancient Japanese black ink drawings. The inherent meanings of strength and simplicity within the art form have been an influence on almost all Japanese culture, including the original founder of the Sansui electronics company.

Since being founded by Mr Khosaku Kikuchi in 1944, the Sansui brand has been firmly associated with simple and reliable products that produce an audiophile sound performance at a sensible price.

SAP-201V STEREO AMPLIFIER £299
This is a solidly built stereo amplifier that breaks all the rules.

It’s the first in its class to offer a built-in DAC, a feature usually exclusive to far more expensive models, and the implemented technology provides fast and accurate signal processing, resulting in a well-balanced, open and precise stereo sound stage. A rigid and solid feel is provided by its all-metal case, and the audiophile-grade components used throughout (along with a high-spec power supply) ensure accurate sound tuning.

WLD-201 NETWORK PLAYER £349
This is a stand-alone audio component that can integrate into your existing hi-fi set-up in much the same way as a traditional radio tuner or CD Player, except it comes with all the advanced technology necessary to access your digital music library.

First of all it has a built-in DAB/DAB+ radio tuner, allowing you to get access to a host of local and national digital radio broadcasts. Secondly, once connected to your home network (via wireless or Ethernet cable connection), it will give you access to over 15,000 internet radio stations from around the globe, many of which are now in digital HD sound formats giving exceptional audio quality. Finally, you can listen to any of the music tracks stored on your computer or network attached storage (NAS) drive, giving you access to your entire library without the need for any other device.

Control of the device is achieved either by the supplied remote control or with Sansui’s own ‘Libretto’ iPod®/ iPhone® application.

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This offers those of us who wish to enjoy our CD collection the chance to experience excellent audio fidelity at an affordable price. Engineered to a high standard with carefully selected components for a ‘best-in-class’ performance at the price point, the CDD-201V is an essential piece of affordable audiophilia.

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The Fusion may be compact but it certainly offers big sound. The acoustically-tuned cabinet combined with the bass radiator guarantees outstanding sound clarity. Fusion also features a very handy retractable iPod dock, so when you want to listen to tunes on the iPod, simply push a button to raise the dock and insert the iPod/iPhone*. When you are listening to the radio, this neatly tucks away behind the system.

Moving arm of retractable iPod dock

SPORTSDAB 2

The SportsDAB 2 DAB/FM digital personal radio is perfect for when you are on the move, in the garden, in the office or at the match. This lightweight, compact and easy to use radio comes with a full screen or rolling text display. Furthermore, it has an integrated battery charger for convenience and complete portability, whilst also saving money on batteries. It comes with a built-in loud speaker if you don't want to use headphones and there's also a built-in antenna to maximise coverage.

SOUND 200

The stunning Sound 200 DAB/FM RDS stereo sound system features a docking station for your iPod and iPhone* as well as MP3/WMA playback via CD, SD card and USB. What's more it boasts a CD player and the ability to record from CD and radio to SD card or USB so you can listen again and again to your favourite shows or transfer tunes from CD or radio to your computer.

ISTREAM

Mid-century design meets the latest in modern technology in the Revival iSTREAM with advanced Wi-Fi internet radio feature. Tune into any radio station from around the world, take the iSTREAM on holiday with you to listen to your favourite stations from back home or stream your personal music collection directly from your laptop. All you need to use the iSTREAM is a broadband internet connection with a wireless router.

*Dock configuration not compatible with the iPhone 5

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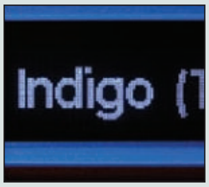
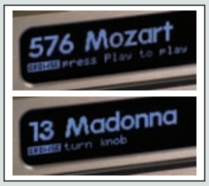
Late home from work or friends round for coffee? Simply press this button and the JB7 will play your CD collection at random so you can unwind or entertain at leisure.



Themed playlists
Select tracks from your collection, give them a colour like red for romance or blue for relaxation then click on that colour on the remote and the JB7 will play them in sequence.

Quick to load
It takes just two button presses to load a CD and just 3-4 minutes to rip it onto the internal hard drive. So you can comfortably load between 20 and 30 in an evening.

Vinyl and Cassettes?
You can record both onto the JB7 as if it were a very large tape recorder. All you will need is a 3.5mm stereo jack, twin phono lead, adapter or connector.



Album and track names are automatically added.
Once you've downloaded a CD the Brennan automatically checks its massive 3 million-strong database to confirm the album title and track names.

Keep your music safe
In case of a breakdown, the JB7 enables you to back up your entire music collection onto an external hard drive so you don't have to spend time re-loading.

Now you can store, browse and play all your favourite digital music as well as your complete collection of up to 5000 CDs on just one machine!

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- Just use USB input and remote control
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- Text search your digital music far quicker
- Bigger display allows you to search and play from across the room

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The NEW 2012 JB7 is available as a 320GB jukebox (holds up to 3200 compressed CDs) and 500GB jukebox (holds up to 5000 compressed CDs) and in a choice of black or grey/green outer casing and brushed metal front casing or dark grey casing and blue metallic front.

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If the Brennan JB7 isn't right for you, give us a call and we will collect it and give you a full refund – we can even arrange collection from a place of work.

The man behind Brennan

MARTIN BRENNAN

Martin is a physicist and computer engineer. He has around 20 silicon chips to his name, has written over a million lines of computer code and co-designed the world's first 64-bit games computer.

The 2012 JB7 will link with a number of MP3 devices including the iPod Classic. To check compatability visit www.brennan.co.uk

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TEAC Reference 01 Series

No matter how you store your music, the new Reference 01 Series from TEAC offers the flexibility to gain the very best sound quality

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FOR MORE INFO

Music today is stored in many different ways. From the conventional CD through to iPad/iPhone/iPod and computers, it's never been easier to access the music you want and listen to it in any number of ways. The new TEAC Reference 01 Series has been designed to give users the very best audio quality in a package that's both flexible and simple to use. The range includes:

A-H01 – AMPLIFIER AND DAC

Both an amplifier and a DAC (digital to analogue converter), the A-H01 is the ideal start point for any system. With its USB input, it's ideally suited to plug into a computer to make the most of those downloaded tracks. Alternatively, its additional digital and analogue connections mean it can form the very heart of any audio system. Just add speakers to fully appreciate how good your music can sound.

The TEAC Reference 01 Series also includes the DS-H01 dedicated iPad, iPhone and iPod docking station as well as the PD-H01 CD transport. As single components used in conjunction with other audio products or as a complete stand-alone system, the TEAC Reference 01 Series has all of the technology, connectivity and flexibility to get the best performance from your music, no matter how it's stored.

MP-H01 – APPLE AIRPLAY AND DLNA WIRELESS HUB

If you use Apple's iTunes and have an iPad, iPhone or iPod Touch, AirPlay is a must for wirelessly streaming music to an audio system. The MP-H01 can connect to any audio system and instantly make it Airplay enabled. There's also good news if you keep your audio on a computer or networked hard drive. The MP-H01 also caters for DLNA compliant products catering for Android devices so streaming couldn't be easier.

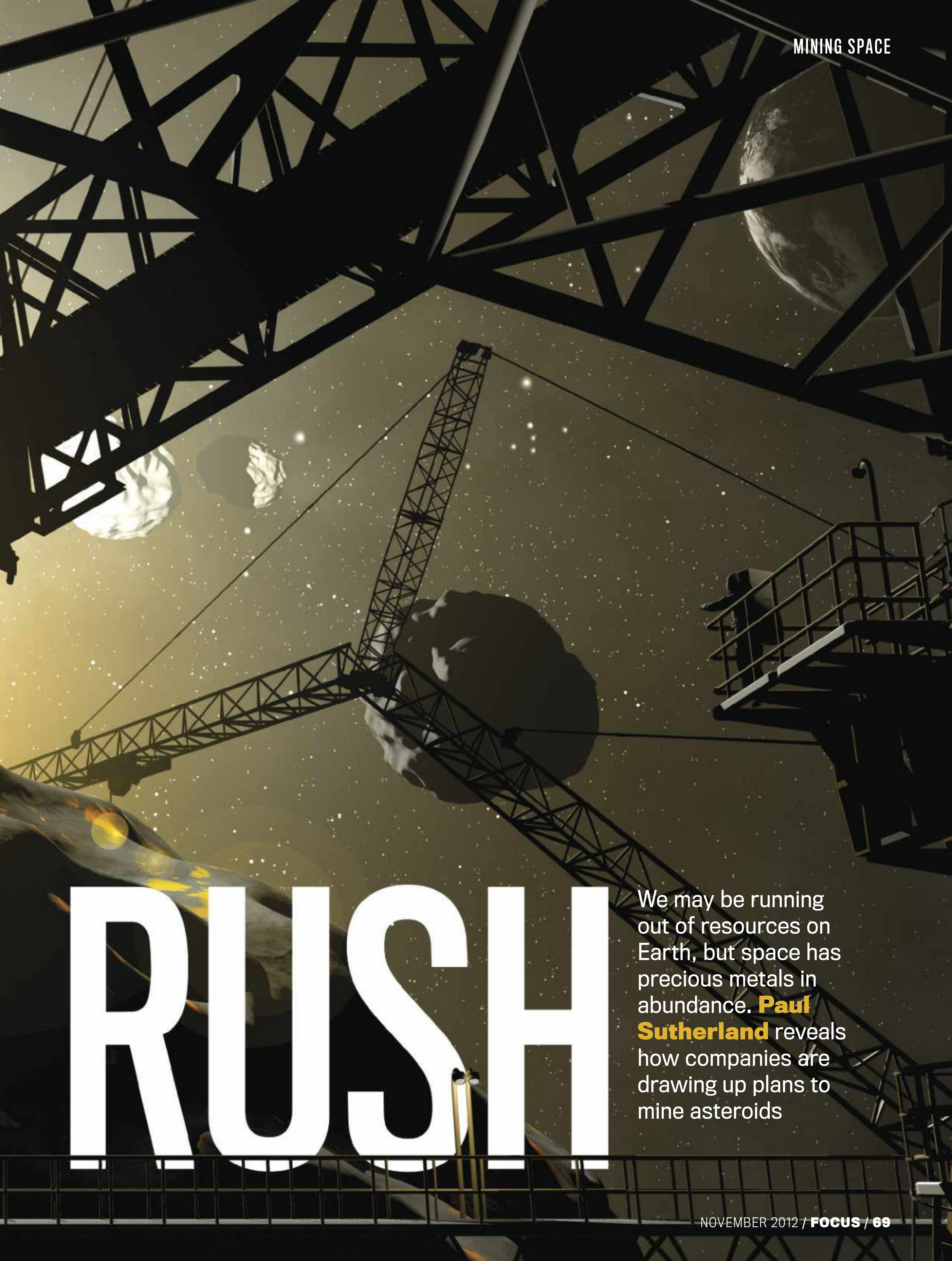
UD-H01 – AUDIOPHILE DAC (DIGITAL TO ANALOGUE CONVERTER)

Anyone who has stored their music digitally will know that when it comes to playback, the sound quality available directly from a computer isn't nearly as good as it should be. This is due to the generally poor-quality DACs in the computer, so upgrading these can make a huge difference to the end result. TEAC's UD-H01 DAC uses the very latest asynchronous USB connectivity technology to bring audiophile sound quality to the music stored on a PC or Mac.

For further information, visit www.teac.co.uk

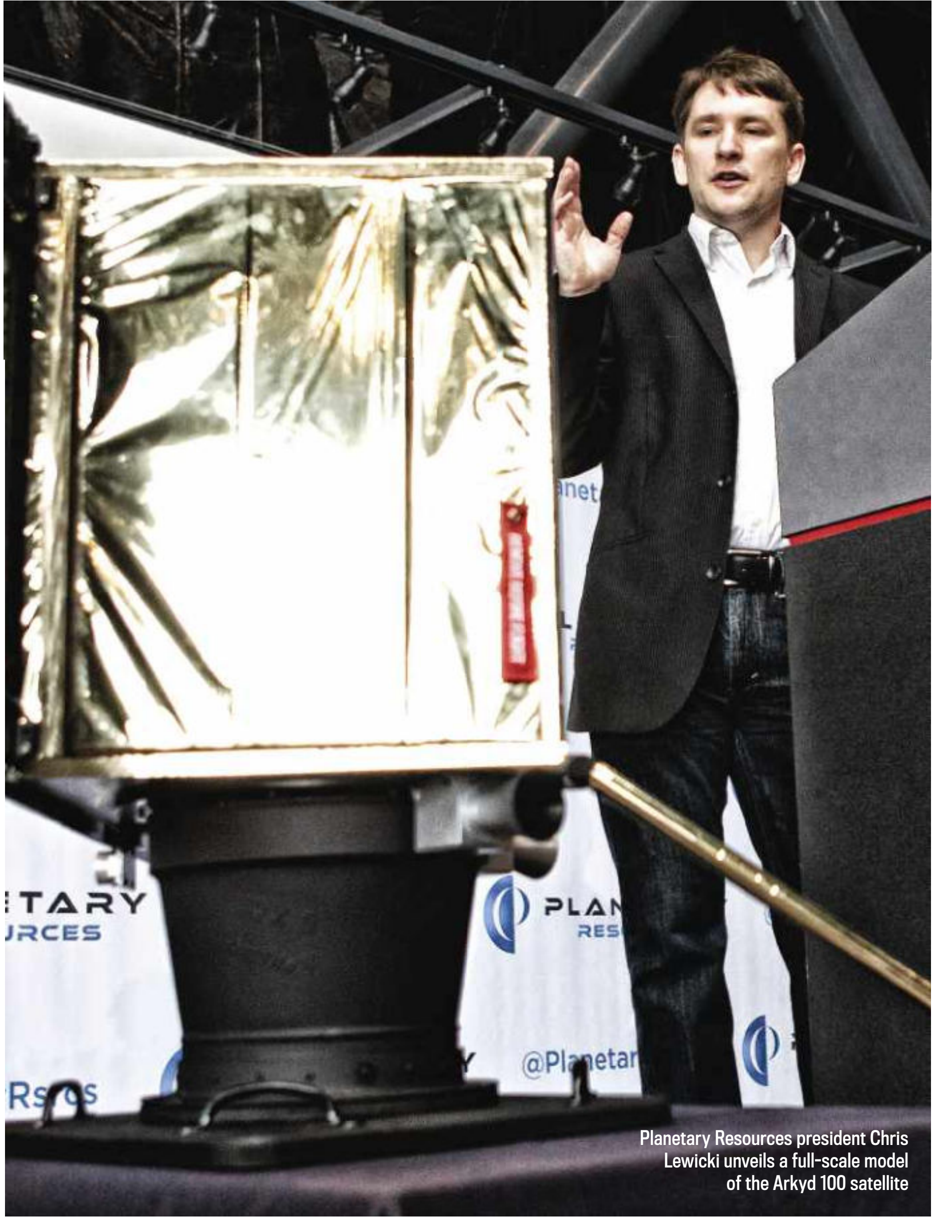
THE NEW GOLD

ILLUSTRATOR: MAGICTORCH



RUSH

We may be running out of resources on Earth, but space has precious metals in abundance. **Paul Sutherland** reveals how companies are drawing up plans to mine asteroids



Planetary Resources president Chris Lewicki unveils a full-scale model of the Arkyd 100 satellite

The Russian space visionary Konstantin Tsiolkovsky penned the science fiction book *Dreams Of Earth And Sky* in 1895, in which he wrote of mankind settling in space and mining asteroids. Since then, the idea of extracting resources from these lumps of rock has been a recurring theme in science fiction novels.

But in April 2012, at a press conference at the Museum of Flight in Seattle, a bunch of billionaires, including Google co-founders Larry Page and Sergey Brin, announced they had formed a new company, Planetary Resources, aimed at making asteroid mining a reality.

“Mining asteroids is currently science fiction and we’re working to make that science fact,” says Planetary Resources president and chief engineer Chris Lewicki, who worked on the NASA Mars landers Spirit, Opportunity and Phoenix. Lewicki knows there are challenges ahead, but says confidently: “I think we’ll be in the proximity of an asteroid and trying to acquire water in very small amounts by the end of the decade.”

Extracting water-ice from asteroids is an attractive proposition, and not just because it would come in handy for future space colonisers. If it is split into its components, hydrogen and oxygen, water becomes rocket fuel. “A large asteroid could be used to create propellant depots and gas stations throughout the Earth-Moon system that rapidly reduce the cost of human spaceflight through the Solar System,” says Eric Anderson, joint head of Planetary Resources. “It is a huge game-changer.”

“For an asteroid that’s 50-100m wide, you’re talking about $40-50 billion worth of resources”

Eric Anderson, co-founder and co-chairman of asteroid mining pioneer Planetary Resources

As well as water, asteroids also contain valuable materials, such as iron, nickel and platinum group metals, which have a huge array of uses (see ‘Asteroid assets’, p71). When the Earth was formed 4.5 billion years ago, molten iron sank to the centre, taking precious metals such as gold and platinum with it. But these metals are distributed throughout the body of an asteroid, making them easier to extract.

FALLING SAMPLES

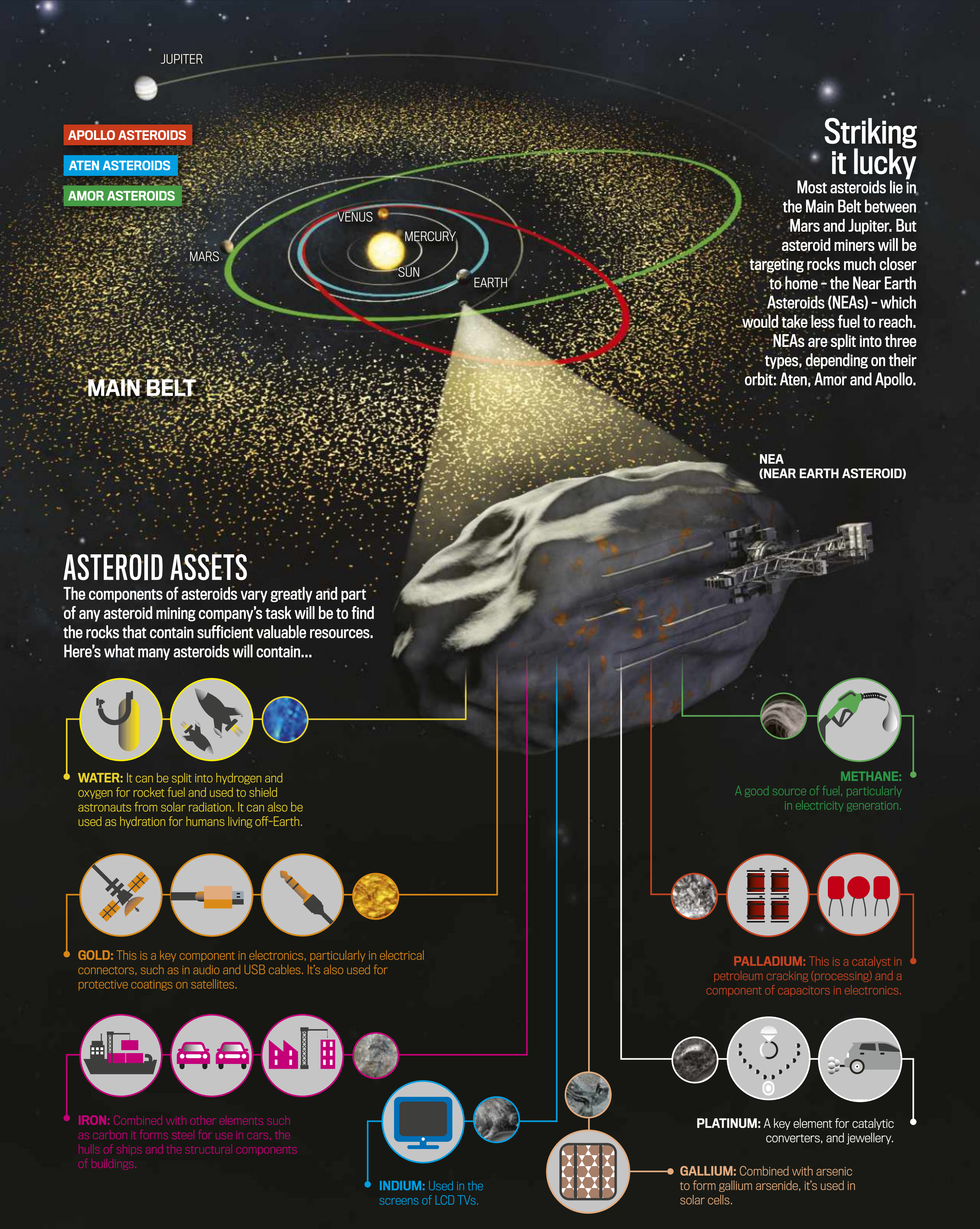
Scientists have already been able to get their hands on many asteroid samples that arrived on Earth as meteorites. “If you picked up a tonne of rock from the Earth’s crust, you would have half a milligram of gold atoms within it,” says Professor Alan Fitzsimmons, who studies the minor bodies of the Solar System at Queen’s University, Belfast. “In a meteorite, there is roughly five times as much. For an incredibly rare metal like osmium, we find there is 10 times as much in meteorites.”

That makes asteroids a valuable commodity. “For an asteroid that’s 50 to 100m wide, you’re talking about $40-50 billion (£25-31 billion) worth of materials there,” says Anderson, whose other enterprise, Space Adventures, has sent several wealthy clients to the International Space Station. “The fact is we live on a little planet in a sea of infinite resources.” These materials could either be used in space – aiding space exploration and colonisation – or brought back to Earth, ensuring that we have plentiful supplies to make cars, mobile phones and TVs.

Lewicki heads a team of over 30 engineers and technicians, many with experience at NASA, who are designing a space telescope to hunt down resource-rich asteroids. The Arkyd 100 telescope will be the size of a microwave oven, have a 22cm mirror and weigh just 20kg. Eventually, a constellation of 10-15 of them will ring our planet. But these satellites won’t just spot asteroids.

60 grammes of space rock will be returned to Earth from asteroid 1999 RQ36 by the NASA OSIRIS-REx mission. Due to launch in 2016, it will cost $1 billion (£620m). Some say this tiny amount proves that asteroid mining is currently uneconomic.

PHOTO: GETTY ILLUSTRATOR: MAGICTORCH, INFOMEN



Striking it lucky

Most asteroids lie in the Main Belt between Mars and Jupiter. But asteroid miners will be targeting rocks much closer to home - the Near Earth Asteroids (NEAs) - which would take less fuel to reach. NEAs are split into three types, depending on their orbit: Aten, Amor and Apollo.

ASTEROID ASSETS

The components of asteroids vary greatly and part of any asteroid mining company's task will be to find the rocks that contain sufficient valuable resources. Here's what many asteroids will contain...

WATER: It can be split into hydrogen and oxygen for rocket fuel and used to shield astronauts from solar radiation. It can also be used as hydration for humans living off-Earth.

METHANE: A good source of fuel, particularly in electricity generation.

GOLD: This is a key component in electronics, particularly in electrical connectors, such as in audio and USB cables. It's also used for protective coatings on satellites.

PALLADIUM: This is a catalyst in petroleum cracking (processing) and a component of capacitors in electronics.

IRON: Combined with other elements such as carbon it forms steel for use in cars, the hulls of ships and the structural components of buildings.

PLATINUM: A key element for catalytic converters, and jewellery.

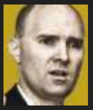
INDIUM: Used in the screens of LCD TVs.

GALLIUM: Combined with arsenic to form gallium arsenide, it's used in solar cells.

FOR AND AGAINST:
Is mining asteroids economically viable?

⊕

Eric Anderson
Co-founder and co-chairman, Planetary Resources

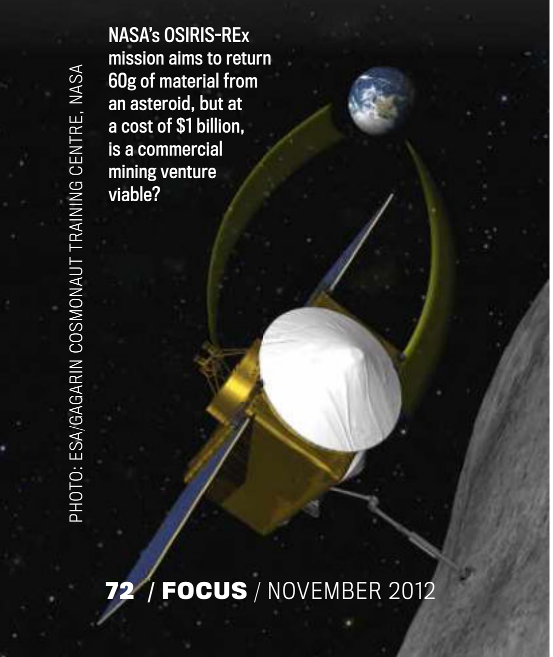


"I often get asked whether bringing back quantities of precious metals will affect the markets. I hope asteroid mining has a big effect: I want to see the cost of energy and resources drop in the long term. Rare metals are essential for use in things like renewable energy, medical devices and microelectronics, so providing them is a viable business. We're not in this to try to make the price higher. We want to use Solar System resources to create a world of abundance."

⊖

Paul Horsnell
Head of Commodities Research, Barclays Capital

"The challenge of asteroid mining is that you use an awful lot of energy in getting there and a lot of energy in bringing it back. From the early figures I saw, it seemed the cost of whatever it was they were mining was just so high that it didn't seem to make any kind of economic sense. It's obviously going to be much cheaper digging a mineral out of the ground in Russia or South Africa than it is going to an asteroid and picking it up."



NASA's OSIRIS-REx mission aims to return 60g of material from an asteroid, but at a cost of $1 billion, is a commercial mining venture viable?

PHOTO: ESA/GAGARIN COSMONAUT TRAINING CENTRE, NASA

50 years' time is when the Earth's accessible stocks of platinum, gold and other rare elements such as tin, copper, lead, silver and zinc could run out.

➔ By studying their albedo, the amount of light that bounces off the space rocks, it will be possible to tell whether they are stony, metallic or carbonaceous. Other sensors, such as infrared detectors, could provide more detail.

Most asteroids are collected in a zone between the orbits of Mars and Jupiter (see 'Striking it lucky', p71) and are debris left over from the formation of the Solar System 4.5 billion years ago. The pioneering prospectors won't be heading out that far any time soon. Instead, they aim to use robots to snare Near Earth Asteroids – rocks that spend at least part of their orbit less than 1.3 Astronomical Units (AU) from the Sun, 1 AU being the Earth-Sun distance.

The Arkyd 100 satellites will later be adapted with a more capable rocket engine and additional scientific instruments to create Arkyd 200 satellites, also known as Interceptors. Two or more of these will be sent to fly past and analyse asteroids passing between the Earth and the Moon, providing what Planetary Resources describes as the 'highest-resolution data'. The final phase of the company's space telescope evolution will be the Arkyd 300, or Rendezvous Prospector, which will be kitted out with deep-space laser communications. This will enable much more distant asteroids to be targeted.

Finding the right asteroid is vital. A report released in 2011 by experts from most NASA centres and several US universities cited carbonaceous, or C-type, asteroids as the best target for mining operations because they offer the most diverse resources. C-type asteroids are also far less solid than the other main asteroid type, the metallic or M-class rocks. They would crumble like a stock cube between your fingers, making it easy to pick out the ice and metals within.

The only problem with C-type asteroids is that they have a low albedo, making them harder to spot. So the sooner the search can start, the better. "We're working on our telescopes right now and anticipate that we'll have a constellation

Like many British men, Tim Peake wears a suit to work, although he dons his as part of underwater training for a trip to an asteroid

Q&A: TIM PEAKE

The UK astronaut has been working with NASA to prepare for an asteroid mission

Earlier this year you spent time in the Aquarius underwater base off the coast of Florida. What were you doing there?
It was a NASA expedition to do research for future missions. At the moment, it's focusing on landing astronauts on an asteroid.

Why go underwater?
It isolates the crew, so it's a good environment to mimic a space mission. The neutral buoyancy is as close as you can get to weightlessness on Earth.

What were you studying?
Things like how to tether your equipment to an asteroid and how to take a core sample. We also had a 50-second communication delay between ourselves and Mission Control, to simulate what communications would be like beyond the Moon.

What equipment did you use for taking samples?
The NASA tools guys have developed some fantastic equipment and techniques they wanted us to try. One involved a climbing rope between two anchor points. We looked at whether it would give us enough stability to take a core sample. We progressed to using extendable metal booms and then moved on to jet packs. Finally, we had a sub that joined us to simulate a space exploration vehicle. It had robotic arms with footplates on them.

Why does NASA want to visit an asteroid?
Asteroids are what's left of the Solar System's building blocks, so they hold four billion years' worth of history. Secondly, they are a source of natural resources. We're also realising that there are more asteroids than we thought. Over 1,500 of them are potentially hazardous, so the better we understand their composition, the better equipped we will be to deal with any planetary defence issues in the future.

Do you think mining an asteroid is feasible?
Absolutely. It's completely feasible, it's just a question of developing the technology.

Were you, as some media reported, training for an actual asteroid mission?
No. We were just doing the R&D at Aquarius – investigating ways we could accomplish such a mission.

> **"We'll have maybe half a dozen eyes in the sky in less than two years' time"**
>
> Chris Lewicki, President and Chief Engineer, Planetary Resources

of maybe half a dozen eyes in the sky in less than two years' time," says Lewicki.

"Our current research is focused on finding ways to demonstrate that any given asteroid contains commercially viable quantities of water or platinum group metals," says Lewicki. But the company is also carrying out preliminary research into the next steps – extracting resources and taking them where they're needed, such as a fuel depot orbiting Earth.

DRAG AND DROP

Rather than extracting raw materials in situ, the 2011 report, funded by the Keck Institute for Space Studies at the California Institute of Technology, envisioned an entirely different approach. It proposed a strategy of bagging up an asteroid in a giant inflatable draw-string enclosure before a rocket thruster stops the rock from spinning. Once stabilised, it would then be moved into a high orbit around the Moon, where it would be accessible to robots and astronauts. It says such a feat could be accomplished by 2025.

But Fitzsimmons sounds a note of caution. "We don't even know if we can move an asteroid yet. We've never tried. And with any ideas we've had so far, you'd be looking at timescales of years to decades to attempt just a small shift in orbit." The Keck Institute envisages a flight time from capture site to lunar orbit of around 6-10 years.

NASA is considering a more detailed analysis of the practicalities of asteroid mining. In August, it announced it was funding a feasibility study into a Robotic Asteroid Prospector, a spacecraft that would act as a test bed for industrial-scale mining technology. Whether the craft gets off the ground remains to be seen. If Planetary Resources continues to make strides with its plans, it could make the mission redundant.

There's no question that mining an asteroid will push our capabilities to the limit. So there will always be the danger that a multi-million dollar mining mission could fail to provide any return. But with the huge resources locked away in asteroids, the pay-off could be huge.

"It is a risky business," says Anderson. "But there is a very large pot of gold at the end of that rainbow." ■

PAUL SUTHERLAND is an astronomy writer and the author of *Where Did Pluto Go?*

Find out more

Mining The Sky: Untold Riches From The Asteroids, Comets And Planets
John S Lewis (Basic Books, 1997)

http://bit.ly/JFfn8Q
Planetary Resources webcast on its plans

BBC WORLD SERVICE

http://bbc.in/JCQVXx
BBC World Service *Science In Action* programme looking at asteroid mining

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TECHHUB

EDITED BY **DANIEL BENNETT**

THIS MONTH

BILL THOMPSON
Using multiple gadgets
p77

JUST LANDED
The smart camera
p78

ULTIMATE TEST
Sleep gadgets
p81

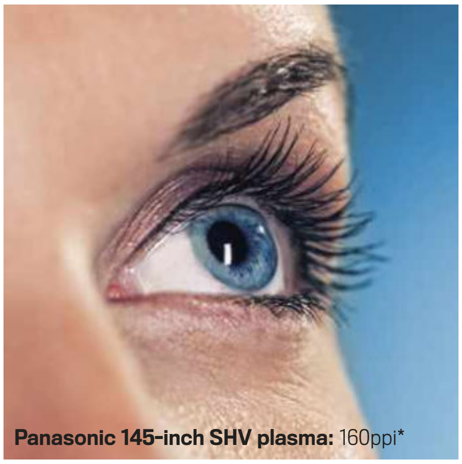
ON THE HORIZON

SUPER HI VISION TV

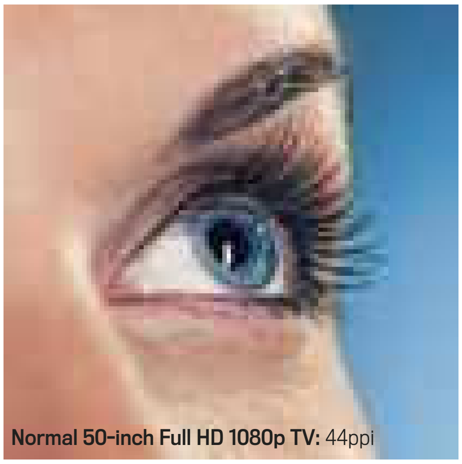
Huge TVs likely destined for footballers' homes no longer get most of us excited, but it's what's within Panasonic's new 1.8m-tall, 3.2m-wide plasma that's pushing the boundaries of technology. At 145 inches in diameter, the screen – fresh from behind-the-scenes trials at the London 2012 Olympics – has a resolution that dwarfs any other visual device. The panel's '8k' resolution (7,680 x 4,320) is capable of displaying a 32-megapixel picture in full, without loss of detail.

This is quite something for a TV; a regular full-HD (1080p) telly shows a mere 2-megapixel image. Technically 16 times more detailed than HD, this new format – called Super Hi Vision TV (SHV) – is set for big things. Its creator is Japanese state broadcaster NHK, which settled on this resolution after experiments into how it related the sense of 'being there'.

The Panasonic 145-inch 8k Super Hi Vision TV is so big it could display life-size players in your living room



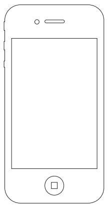
Panasonic 145-inch SHV plasma: 160ppi*



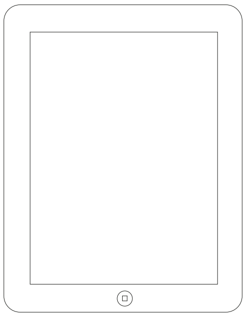
Normal 50-inch Full HD 1080p TV: 44ppi

*ppi = pixels per inch; the pictures above simulate how different resolutions would appear

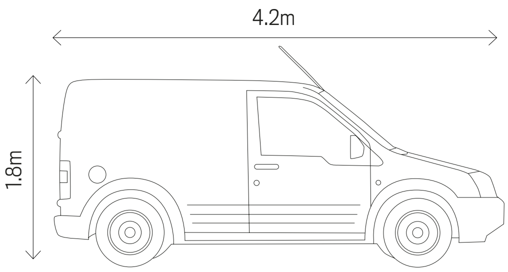
IN NUMBERS:



iPhone 5
326ppi



iPad
264ppi



At 1.8m x 3.2m, Panasonic's Super Hi Vision TV is about the size of a Ford Transit van (1.8m x 4.2m)

The theory goes that a 32-megapixel image is enough for the human brain to be truly immersed, and convinced that the image is real. But there are other benefits that only a truly giant screen – or projection – can offer. Since the image is so detailed, and the frame so huge, a Super Hi Vision video camera doesn't need to pan; an entire shot of a tennis court can be presented as a static end-to-end image. Your eyes do the editing.

When we saw it, it was clear that the 3D format had a major challenger. To call it a 'window on the world' risks cliché, but 'long-take' sequences, devoid of distracting cuts and close-ups, reveal so much depth and detail that pictures seem to almost pop out of the screen.

Coming to life

In an effort to get SHV into homes – at least in the long-term – Sharp has demonstrated an 85-inch LCD TV with an identical resolution, and technicians are working to reduce the size still further, though cramming in the extra pixels into less and less space is proving tricky.

And if you're wondering what there'll be to watch, broadcasting SHV TV has already been achieved. A portion of London 2012 was filmed in SHV by the BBC, using NHK's three SHV cameras, and broadcast across the web on a closed circuit network at 500MB/s, but only to a few specially created cinemas.

That athletic outing looks set to be repeated at Rio 2016 and in 2020, when NHK could find itself the host Olympic broadcaster if Tokyo wins out against Madrid and Istanbul. By then NHK is planning to broadcast an SHV TV channel into Japanese homes.

As for watching SHV on Blu-ray, NHK can currently squeeze an hour of SHV footage onto a 64GB hard drive. This equates to over 13 Blu-ray discs, so a new format might be necessary. And that's not the only new equipment that could arrive as a result of SHV. The SHV specification comes with 22.2 multi-channel surround sound, which would dwarf 5.1 systems currently used for home cinemas.

It's a way off... but this could be the kind of TV we'll be watching in 2020.

JAMIE CARTER is editor of *Home Cinema Digest*

TECHOMETER

WHAT'S HOT

4G MOBILE BROADBAND

Mobile internet is about to get fast, very fast. Everything Everywhere, the company that owns Orange and T-Mobile, is launching a 4G network called EE that will cover 16 UK cities this month. The technology should allow transfer rates of up to 125MB/s, but with different chipsets, telephone masts and the vagaries of coverage, it won't quite reach those speeds. That said, it's still far superior to 3G, enabling you to stream HD movies on the go.

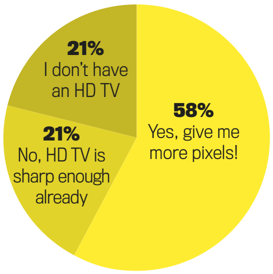
WHAT'S NOT

iTUNES

Apple's store once used to sell songs and songs alone. But now TV shows, films and apps are also on offer, making iTunes a bloated, hard-to-navigate piece of software that's quite unlike the rest of Apple's offerings. The people at Apple clearly think the same as it has signalled it will completely overhaul the service by the end of the year. It'll also kill off its social network based around music, Ping, proving that not everything Apple does is 'magical'.

READER POLL

Do you want a better resolution than HD TV? Here's what readers have said so far. Add your opinion at j.mp/UltraHDTV



ILLUSTRATOR: LAUREN GENTRY

EARLY ADOPTER

BILL THOMPSON

Jack of all trades, master of none?

Many of my columns have been written in cafés. Not only is the coffee supply effectively infinite, but there's something about the shared public/private space and the way we manage our interactions with each other that reminds me of the ways we are learning to cope with being online all the time.

The always-on world doesn't surprise me much. Having been online in some form or other since 1984, I've seen the internet evolve and knew that getting connected would become a lot easier. That said, I did underestimate just how much easy access to the network would change the patterns of our daily lives.

Now anyone with a smartphone or 3G-equipped tablet is only one click away from the internet. For some, the way the online world has bled through into daily life has been disconcerting. But for me, it's been inspirational, allowing me to connect to others and information in an ever-expanding number of ways.

But the one thing I didn't predict, the one thing that I got very wrong indeed, was the failure of convergence – the dream of a singular device that would meet your every technological need. Ten years ago I carried a mobile phone with me everywhere, and often lugged a heavy laptop on my travels. I imagined a future where my phone and laptop would become one and that each of us would carry around a powerful processor in a pocket or bag, that used a short-range networking system like Bluetooth to connect it to screens, keyboards, headsets and other peripherals.

What I didn't see coming was that I'd actually carry more devices with me than before. Now I habitually carry with me a laptop, a smartphone *and* a tablet computer, each significantly more powerful than my desktop computer of just a couple of years ago. And it doesn't seem that the new iPhone, the updated iPad or the latest generation of ultrabooks are likely to change my behaviour.

Of course it's a privileged and wealthy group that has the luxury of carrying around several gadgets with them everywhere they go, but it is worth looking at the behaviour of these people to uncover deeper truths about how new technologies will work. We only saw how useful portable computers were because people bought the expensive early laptops, while early adopters of the iPad showed that cheaper tablets had a niche to fill.

The deeper truth here is that when processors are everywhere and screens are ubiquitous we, as humans, still like to use different devices for different purposes. I rarely make voice calls, but my iPhone is great for tweeting, messaging and status updates. I like to read books and browse the web on my Nexus 7 – smaller than the original iPad, and a lot lighter. But I create on my laptop, where I need a keyboard and trackpad for writing and editing.

The idea that different tools fill different niches is obvious, as any carpenter will tell you, but for a while we seemed to act as if all computer-based devices were somehow equivalent. Now it's clear that this is not, and never will be, the case. Not only does a carpenter have lots of different tools, they even have lots of different hammers. Some tasks need just the right tool, and just because a device has a processor in it doesn't mean it can do everything.

Bill Thompson contributes to news.bbc.co.uk and the BBC World Service

TELL US WHAT YOU THINK!
Visit our forum at sciencefocus.com/forum

COMING SOON

3 MONTHS

VAIO TAP 20

You might think Sony's new desktop PC looks like a giant tablet, and you'd be right. The 20-inch touchscreen PC can be used like a normal tabletop computer with a keyboard and mouse, or you can unplug it (the base unit has a three-hour battery life) and use it like any other Windows tablet. *Sony.co.uk*

+ **Basic Band** An accelerometer, heart rate tracker, thermometer and sweat sensors are all packed into a wristwatch that visualises your health. *Mybasis.com*

+ **Nintendo Wii U** This will be on every kid's Christmas list, big or small. Like the original Wii, the console offers motion-controlled interaction, but with a touchscreen controller opening up new avenues of fun for games developers to explore. *Nintendo.com*

6 MONTHS

LYTRO

Never take an out-of-focus snap again with this revolutionary new camera. A combination of a clever lens system and smart software lets you select the focus *after* you've captured a shot. It's already on sale in the US, and is expected to arrive on UK shores in the first quarter of next year. *Lytro.com*

+ **Microsoft Surface** With a super-thin keyboard and touchpad add-on, this could be a worthy alternative to Apple's iPad. *Microsoft.com*

+ **Nest** A thermostat that could slash your bills. It adapts to your habits to heat your home economically. *Nest.com*

9 MONTHS

XBOX 720

The president of EA games told Bloomberg News recently that his company was already readying games for the next generation of consoles. With coders having got their hands on development kits for the next Xbox, codenamed 'Durango', we imagine Microsoft's new games console will be first to hit the shelves next summer. *Xbox.com*

+ **Project Glass** Messages, maps and information from the web will all be overlaid on top of your view with Google's new vision for the internet. *J.mp/projectglass*

+ **Facebook Phone** Facebook's hiring of former Apple and Palm employees suggests its own phone is in the works. *Facebook.com*

JUST LANDED

APPY SNAPS

We've had smartphones and smart TVs, but now cameras are getting the 'smart' treatment. **Jamie Carter** tests the first of its kind: the Samsung Galaxy Camera

How does the Galaxy differ from a compact camera?
With a touchscreen, apps, Wi-Fi and a 3G SIM card slot, the Samsung Galaxy Camera feels more like a smartphone than a compact camera. It actually runs on the Android operating system used in many smartphones, so all the apps from the Google Play store are at your fingertips, regardless of whether they belong on a camera or not. And just like your smartphone, it can GPS tag all your photos and upload them direct to Facebook and Twitter. Powering all this is a 1.4GHz quad-core processor, so in terms of computing ability it's by far the smartest camera around.

Its camera specs aren't to be sniffed at, either. A 21x optical zoom, 16.3-megapixel image sensor and wide-angle lens make it a formidable snapper in its own right, though images do admittedly fall slightly below the standard you'd get for a similarly priced camera without all the extras. It's big too: at 129x7x19mm it's larger than a smartphone, and considerably heavier than the average compact camera.

Why do I need a camera with built-in apps?
For editing and sharing photos on your camera. Photography apps that edit your photos are hugely popular and powerful tools for smartphones, so it only seems logical that they would make their way onto something with a better image sensor and zoom. With the Galaxy Camera you can use the likes of Adobe Photoshop Express, Instagram or its own built-in Photo Wizard app to improve your images on the fly. Then you can instantly upload them to social networks, back them up on cloud storage sites like Dropbox or email them to your friends and family.

Smarter still, there's a Remote Viewfinder app that enables the Galaxy Camera to be controlled from afar by any device running on Android. For example, you could place the camera on a tripod beside a bird table while you sit inside – even on the other side of the world – and get a live feed, activating the shutter whenever you want. As well as not scaring away wildlife, you won't nudge the camera while pressing the shutter button.

Is it easy to use?
At 4.8 inches across, the LCD touchscreen is sharp, with swiping through pages of apps – identical to a high-end smartphone – a familiar process. The quad-core processor inside ensures photos are saved quickly, and apps loads instantly, though our favourite feature is voice control. Uttering commands like "Zoom in" and "Shoot" makes photography completely hands-free – definitely handy for those perennially tricky holiday self-portraits.

Those who pine for the manual controls of a digital SLR also get a nod, with a variety of dials – in the form of touch-activated graphics – to control exposure, aperture, shutter speed and ISO.

What's the catch?
Although it does have both Bluetooth and Wi-Fi, if it's to work more than 50m from your home a 3G SIM card, like the one in your smartphone, is a must-have. Uploading pictures in full resolution could eat through a lot of your data allowance, however.

While picture quality is superior to a smartphone, don't expect it to match a DSLR, as it'll struggle in low light situations. But for now, this camera is blazing a trail.

SAMSUNG GALAXY CAMERA
£399, WWW.SAMSUNG.CO.UK

1

2

3

4

5

6

APPLIANCES OF SCIENCE

1 SENSITIVE SHRUBS

It's just as well our poor maltreated office plants can't speak – they'd constantly be pleading for a drink of water. Which is why we probably won't be buying a Koubachi Wi-Fi plant sensor. It promises to "give your plant a voice" by monitoring soil moisture, light intensity and temperature, and generally keeping you updated on its state of health via your smartphone or PC. We'll stick to cactuses.

Koubachi
koubachi.com; €89

2 KEEP YOUR KEYS CLEAN

If we put one of our keyboards under the microscope, we'd no doubt see a menagerie of nasty bugs and bacteria thriving on the crumbs and other gunk that's found its way into the crevices over the years. This washable keyboard could bring and end to all that, since it's built to handle a soapy scrubbing in the sink. Just don't put it in the dishwasher – high temperatures are likely to melt it.

Logitech Washable Keyboard
logitech.com; £34.99

3 COMPLETE CONTROL

Do you dream of controlling every aspect of your home from your phone? SmartThings could be the key. These devices retrofit your existing gadgets with a web connection, enabling you to turn them on and off via a smartphone app. You can also pair them with motion sensors, to make your home more secure. Its makers hope there'll soon be other licensed sensors, such as thermostats or smoke alarms.

SmartThings
smartthings.com; £TBC

4 PEDAL POWER

A bicycle dynamo that turns your pedal power into electricity for your lights is nothing new. The EcoXPower adds an extra trick by including a USB cable that'll charge your smartphone or GPS device while you cycle. Your phone or sat-nav can also be mounted on your handlebars in a waterproof, transparent pouch. Now if only there was one big enough to power the whole house…

EcoXPower bicycle phone charger
ecoxgear.com; $99.99

5 SPLIT PERSONALITY

The touch-sensitive nature of Windows 8 has opened the door to a world of new devices. The best so far is this: a laptop with a detachable screen that can be used as a touchscreen tablet. When you're working, the lower keyboard and touchpad give you the tools to create and edit; when you want to read, surf or watch video, simply pull the screen off the base and use it like any other tablet.

Samsung Ativ Smart PC Pro
Samsung.com; £TBC

6 GHOST RIDER

'Silent but deadly' is the best way to describe this electric bike. Its noiseless electric engine means that if drivers don't see you coming, they won't hear you either. If that doesn't scare you off, its 91bhp and 90-mile range make it a perfect city warrior. Its electric engine can deliver all its power at once, taking you from 0-60mph in less than four seconds – perfect for getting up to speed in busy traffic.

Agility Saietta R
saietta.com; from £11,970

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ULTIMATE TEST

REST ASSURED

The extra hour of winter darkness may not be welcome for everybody. With the help of a leading sleep scientist, Joe Minihane tests gadgets that promise a better night's kip

WHY WOULD I WANT ONE?

As any insomniac will tell you, a bad night's sleep can ruin your whole day. Yet while most people appreciate how their health is tied to their diet and exercise, few realise how changes to their sleep pattern can have a knock-on effect during waking hours. These sleeping gadgets give you more control over your slumber, helping you feel more awake during the day.

WHAT DO THEY DO?

There are myriad approaches to supposedly fixing bad sleeping habits. These include anything from a simple relaxation recording to help you drift off, to a monitor that tracks your brain while you're asleep. Essentially, they aim to supplement good advice about sleep, such as cutting out caffeine. However, they're not an alternative to sleep therapy for serious disorders.

WHAT SHOULD I LOOK OUT FOR?

It depends what sleep problem you're looking to solve – is it simply getting off to sleep, or maintaining quality sleep once you've drifted off? Read on to find out what these sleep gadgets can do for you. ➔

JOE MINIHANE is an insomniac and freelance tech journalist

PROF KEVIN MORGAN is director of the Clinical Sleep Research Unit at Loughborough University

PHOTO: STUDIO4PHOTO.CO.UK

MARSONA 600A

£89.99, www.whitenoisemachine.co.uk

It might resemble a burglar alarm, but thankfully the Marsona 600A doesn't emit a shrill siren in an attempt to get you to sleep. In fact, it's a white noise machine aimed at cutting out any infuriating racket from noisy neighbours or traffic revving past your bedroom window.

There are six sound options to choose from: lakeshore, surf, country evening, white sound, thunderstorm and brook. Surprisingly, none of these sounded looped or artificial in any way, although we definitely preferred the more natural sounds of the lakeshore or the brook to the 'TV after midnight' tones of white sound. Selecting a sound is simple, while the volume can be amped up to mask almost any sound. It was especially effective in cutting out the pumping sounds of Latin dance music at 3.30am from our dear friends next door.

It can be quite hard to get used to, though. For the first few nights we took longer to doze off with it on than usual, but after a few nights' use, the sound quickly becomes part of your bedtime routine. It's a smart choice if you live on a street where no-one seems to understand the concept of keeping their music down after 11pm – a common complaint among city dwellers.

The sleep scientist says: "White noise machines can certainly help mask noises that prevent us from dropping off to sleep at night, especially if that noise has an emotional component. One of the reasons things like rain and sea noises fail to keep us awake is that they're emotionally neutral. If next door's dog is barking, it's not just the noise that winds you up, it's the emotional component of the noise. Long term, there could possibly be benefits to using this white noise machine for some people under certain circumstances."

FOCUS RATING ■■■■□

PZIZZ SLEEP FOR iPHONE

£3.99, www.pzizz.com

Smartphone apps that claim to help you sleep are almost as ubiquitous as time-wasting games and productivity add-ons. Among standalone sleep apps (as opposed to those that work with hardware), Pzizz is the pick. At £3.99, it's relatively expensive in App Store terms. However, the fact that it generates a new track to send you to sleep every time you press Start, and has some clever customisation tools, makes it a worthwhile punt if you struggle to ease into sleep.

The idea here is to soothe you to sleep with a blend of voice and music, with users able to tweak how much of each they can hear before starting the process. Tracks can last from just 15 minutes, all the way up to 10 hours. We went with a short half-hour session, with the voice turned to 50 per cent and the music a tad louder at 60 per cent. Once we got past the *Let Go With Alan Partridge* connotations, the soothing voice was surprisingly conducive to winding down. The advice on developing and maintaining 'sleep rituals' is smart and tallies with the latest scientific advice about developing a nightly routine to combat sleep problems.

The sleep scientist says: "This is what we used to call a relaxation tape in the old days. The assumption all such relaxation recordings make is that the barrier to getting to sleep is emotional and physical tension in the individual. We know from the evidence that some forms of auditory pre-sleep relaxation, usually a spoken voice giving relaxation instructions, can work. But the jury is still out on whether there are actually certain types of completely neutral, word-free tones and music that can help get people to sleep. There may be a small number of people for whom this would be preferable to a clinical relaxation therapy."

FOCUS RATING ■■■□□

ZEO SLEEP MANAGER PRO+

£119, www.myzeo.co.uk

Donning its headband makes you look like an extra from *Star Wars*, but there's more to the Zeo than indulging your science fiction fantasies. The mobile version on test here works in conjunction with a free iPhone app, connecting to said headband via Bluetooth in order to track your REM, light and deep sleep. It serves up a dedicated 'ZQ' score, which can be compared to average scores on a bundled information card.

It has to be said that the headband, actually a single EEG (electroencephalography) sensor, can feel a little uncomfortable at night, especially as it has to sit tight to the forehead. You also need to remember not to put your iPhone into sleep mode when you go to bed, otherwise the tracking system won't work.

Seeing the results of your sleep on a graph is undoubtedly fascinating. But when it comes to helping those with sleep issues, the simple 'personal sleep coach' advice, which can be accessed via the app, is far better. After rating your sleep (good, bad, OK), it serves up basics such as getting to bed at the same time regularly and when to nap. Useful, but not revelatory in and of itself.

The sleep scientist says: "In terms of technological and theoretical grounding, Zeo is very credible. That said, it's a one-channel EEG recorder and when we do research recordings, we never use fewer than three channels. Most people are not going to like sleeping with a band around their head that makes them look like Wonder Woman – we know this from trying to get people to wear EEG monitors in the laboratory. But the critical part of Zeo isn't actually going to be in the sleep monitoring itself, but in the advice it gives you after a few readings to help you manage your sleep."

FOCUS RATING ■■■□□

LUMIE BODYCLOCK ACTIVE 250

£99.95, www.lumie.com

A 'dawn simulator', Lumie's Bodyclock Active 250 doesn't recreate the almighty racket of morning birdsong in your bedroom. Rather, it's designed to help users ease themselves awake when it's dark and miserable outside.

Essentially a take on the classic clock-radio, it features a large lamp across the top, which can be set to sunset mode at night and sunrise mode in the morning. You can tinker with the settings to have the light come on quickly over a 15-minute period, or more gently over 90 minutes. If you're still sleeping once the light's come up to full beam, a traditional alarm will beep you from your slumber.

Set-up is swift and easy, while both sunset and sunrise are great at making the entire experience of going to bed and dragging yourself out of the covers far more pleasurable. It works especially well in dark rooms during lighter months, but it still doesn't dispense with the fact that getting out of bed on a weekday is one of life's ultimate drudgeries. Lumie claims it can help complement treatments for those suffering from Seasonal Affective Disorder (SAD), but if you do suffer from this debilitating problem, you should see your GP first to talk through therapy options.

The sleep scientist says: "Dawn simulation has been a background consideration in biological research for some time now, as we've learned more about the night-time hormone melatonin that starts to peak as the light diminishes. There are also 'awakening' hormones like cortisol that kick in when it's bright. This is a device that is loosely based on this science. For some this might be a pleasant adjunct to their bedroom. It's also very convenient, as it saves you having to get up in the dark and turn the light on."

FOCUS RATING ■■■□□

Issue Number 1 - FREE

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Q&A

YOUR QUESTIONS ANSWERED

BY OUR EXPERT PANEL

SUSAN BLACKMORE
Susan is a visiting psychology professor at the University of Plymouth. Her books include *The Meme Machine*

DR ALASTAIR GUNN
Alastair is a radio astronomer at the Jodrell Bank Centre for Astrophysics at the University of Manchester

ROBERT MATTHEWS
After studying physics at Oxford, Robert became a science writer. He's a visiting reader in science at Aston University

GARETH MITCHELL
Starting out as a broadcast engineer, Gareth now writes and presents *Digital Planet* on the BBC World Service

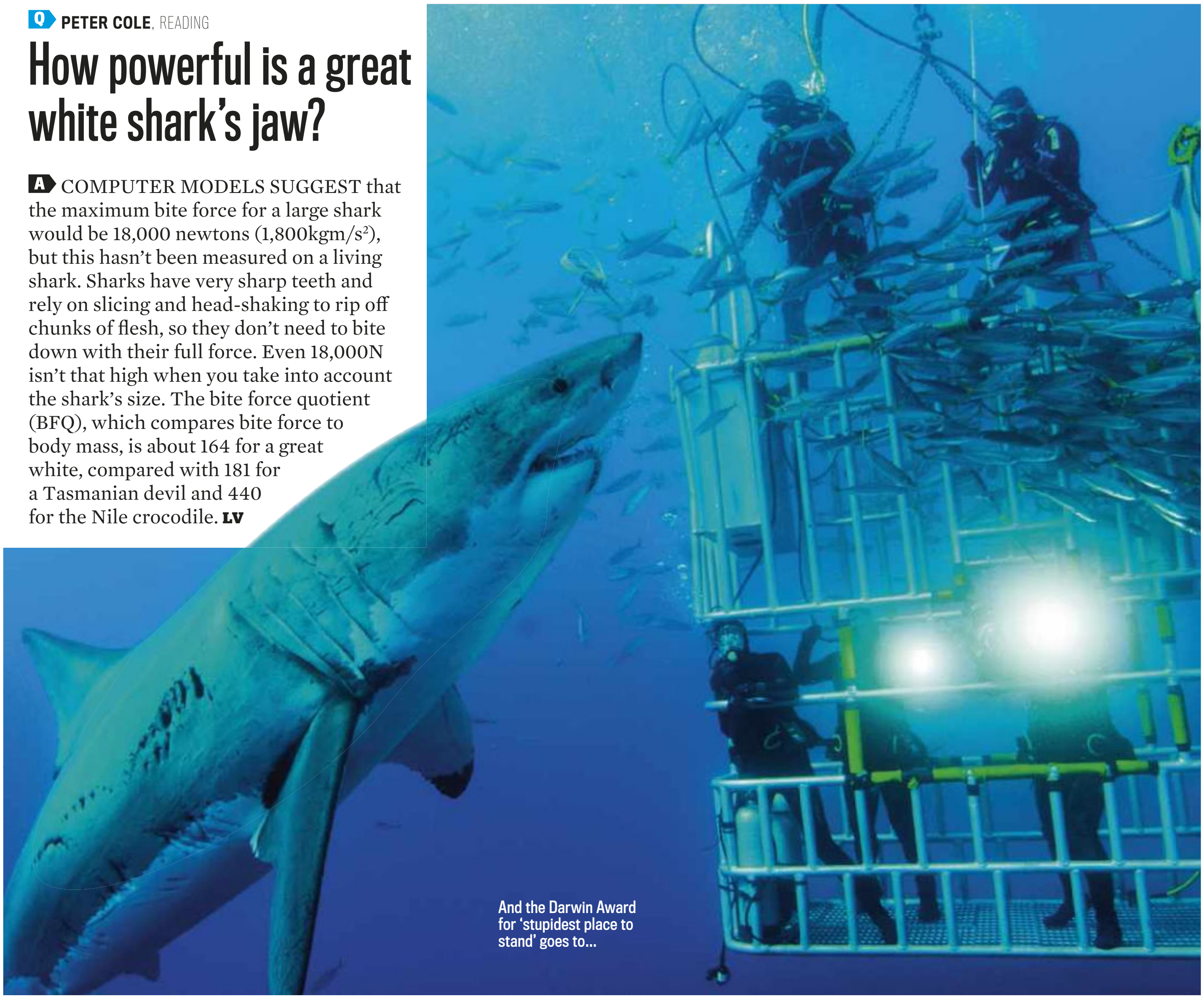
LUIS VILLAZON
Luis has a BSc in computing and an MSc in zoology from Oxford. His works include *How Cows Reach The Ground*

EMAIL YOUR QUESTIONS TO questions@sciencefocus.com
or post to *Focus* Q&A, Tower House, Fairfax Street, Bristol, BS1 3BN

Q **PETER COLE**, READING

How powerful is a great white shark's jaw?

A COMPUTER MODELS SUGGEST that the maximum bite force for a large shark would be 18,000 newtons (1,800kgm/s^2), but this hasn't been measured on a living shark. Sharks have very sharp teeth and rely on slicing and head-shaking to rip off chunks of flesh, so they don't need to bite down with their full force. Even 18,000N isn't that high when you take into account the shark's size. The bite force quotient (BFQ), which compares bite force to body mass, is about 164 for a great white, compared with 181 for a Tasmanian devil and 440 for the Nile crocodile. **LV**



And the Darwin Award for 'stupidest place to stand' goes to…

PHOTO: DAVID LITCHFIELD

In Numbers

21.5 billion

is how many megabytes of images are stored in Google Street View

Q JOHN WALKER, HALIFAX

Why can't nuclear waste be sent into outer space?

A THE WORLD'S NUCLEAR reactors have generated tens of thousands of tonnes of high-level nuclear waste, and the current solution is to simply store the stuff. This is not without its dangers: an explosion at the Mayak nuclear waste facility near Kyshtym, Russia in 1957 remains the third worst nuclear disaster in history, after Chernobyl and Fukushima. In the search for alternatives, the possibility of firing the waste out of the Solar System or into the Sun has been investigated many times, but the use of rockets raises the threat of an accidental release of the waste into the atmosphere if there was an explosion. Some studies have looked at the possibility of using high-powered lasers to blast capsules into space, but economic, reliability and safety issues – plus likely legal challenges – have so far ruled out this option. **RM**

Dumping waste in space would not be a popular move

Q CHARLOTTE MABEY, BRIGHTON

Why can't babies breathe through their mouths?

A NEWBORN BABIES HAVE a much larger tongue relative to their mouths than adults, and the epiglottis is pushed up against the soft palette. This provides an almost complete seal for the airway via the mouth, which allows babies to breathe and swallow at the same time. If the nose gets blocked by a cold or a physical obstruction, the mouth serves as an emergency back-up but a baby generally needs to be crying to generate enough pressure to force air through the narrow opening. By six months, the muscles of the tongue, face and soft palette have developed more and the epiglottis moves downwards to disengage from the soft palette. This increases the risk of choking when swallowing but allows mouth breathing.

More importantly, it allows us to form the range of vowel sounds required for speech. In contrast, chimpanzees breathe only through their noses and can't say "I", "ow" or "oo". **LV**

Very young babies only breathe through their noses

Q ALAN SIDDELL, DERBYSHIRE

Is it only humans that have made other animals extinct?

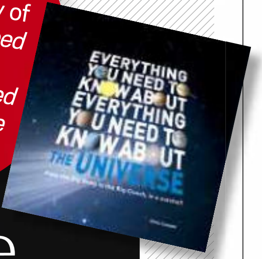
A NOT AT ALL. Until 2 million years ago there were no humans, so all extinctions before that were caused by something else. For mass extinction events, such as those at the end of the Permian and Cretaceous eras, this may have been a catastrophe such as an asteroid impact. But the bulk of evolutionary progress is driven by one animal out-competing its close relative and driving it extinct. We evolved from primates, which evolved from four-legged mammals, which evolved from fish, which evolved from invertebrates. Modern examples of all of these animals still exist but the specific species that were our direct ancestors do not, because they were driven extinct. That process continues: the red squirrel is being driven extinct by the grey squirrel, for example. **LV**

The grey squirrel is slowly eliminating its red cousin

PHOTO: ALAMY, THINKSTOCK X3, PRESS ASSOCIATION

QUESTION OF THE MONTH

WINNER!
Adam wins a copy of *Everything You Need To Know About Everything You Need To Know About The Universe* by Chris Cooper


EVERYTHING YOU NEED TO KNOW ABOUT EVERYTHING YOU NEED TO KNOW ABOUT THE UNIVERSE

Q **ADAM DOOLEY**, MANCHESTER

Would it be possible for a gas giant like Jupiter to ignite?

A STARS BURN AS a result of thermonuclear reactions deep in their cores. An object with a mass less than about eight percent of the Sun's cannot ignite significant nuclear reactions in its core. These objects are 'failed' stars called brown dwarfs. In their youth, brown dwarfs do generate some energy from fusing deuterium into helium nuclei, but older brown dwarfs only radiate a small amount of heat due to their slow contraction. The dividing line between these brown dwarfs and gas planets occurs at about 1 per cent of the mass of the Sun. Objects less massive than that can never achieve the core temperatures required for thermonuclear reactions. This corresponds to about 13 times the mass of Jupiter, meaning that Jupiter itself is incapable of ever 'igniting'. Jupiter lies pretty close to the limit of what we'd call a gas giant. But by definition, if a gas giant is massive enough to 'ignite' deuterium fusion it is not a gas giant at all, but a brown dwarf. **AG**

Jupiter is in no danger of suddenly bursting into flames. Phew...

Many children grow taller than their parents thanks to a better diet

Q **SARAH LUNDEY**, MANCHESTER

Is height determined mostly by fathers?

A NO. ADULT HEIGHT is determined by a mixture of genes, diet and hormones. We inherit our genes equally from each parent; indeed, height can be predicted fairly accurately from parents' heights. But we can only grow to our full potential if we have enough good food during childhood and adolescence – and where food is concerned, it may be that mothers have a greater effect. **SB**

Q **LUKASZ MUSIALOWICZ**, LONDON

Do menthol cigarettes make men infertile?

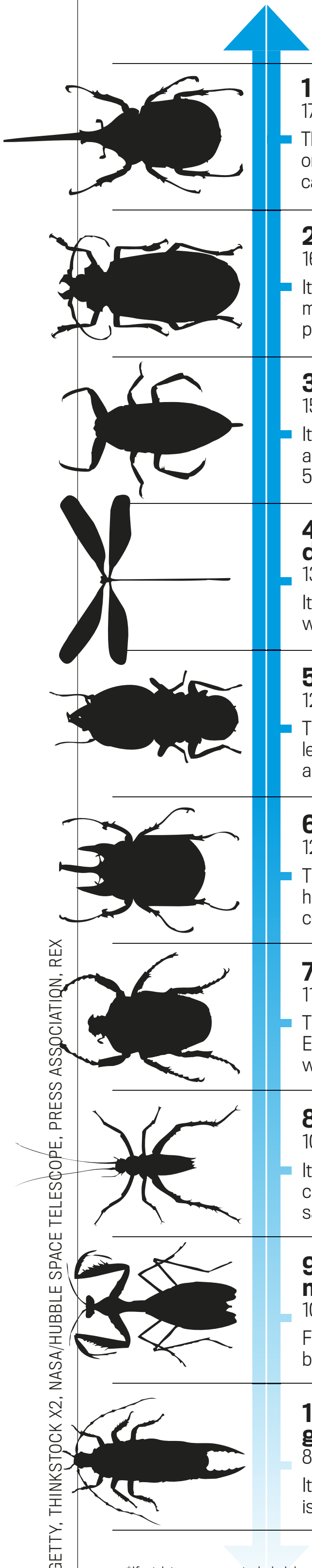
A SMOKING AFFECTS THE blood vessels, causing erection problems, and results in the production of fewer, slower-swimming sperm. Menthol cigarettes aren't necessarily any worse, although one study found that smokers of menthol cigarettes take longer drags. **LV**

Q **LUKE ANDERSON**, TONBRIDGE

How would fizzy drinks behave in space?

A WITHOUT GRAVITY, THERE is no density gradient within the drink, so its bubbles float around randomly inside the liquid. Occasionally a bubble strikes another with enough force to overcome the surface tension and they merge, so over time the bubbles coalesce into a few large bubbles that squash the others into a sort of static foam. **LV**

TOP TEN
LONGEST INSECTS
(excluding stick insects*)



1. Hercules beetle
170mm long
The strongest creature on Earth by size, able to carry 850 times its weight

2. Titan beetle
167mm long
Its curved, sharp mandibles can snap pencils in half

3. Giant water bug
150mm long
It has a venomous bite and can feast on prey 50 times its size

4. Giant helicopter damselfly
135mm long
It can use its 190mm-wide wings to hover

5. African termite
125mm long
The queen attains this length, but other adults are a third of the size

6. Elephant beetle
120mm long
The male uses a curved horn on its head in combat with other males

7. Goliath beetle
110mm long
The heaviest insect on Earth in its larval stage, weighing up to 110g

8. Giant weta
100mm long
It resembles a large cricket and weighs the same as three mice (35g)

9. Giant African mantis
100mm long
Females can get this long, but males are smaller

10. Saint Helena giant earwig
84mm long
It's found on an isolated island in the south Atlantic

*If stick insects were included they would take the top 10 places! The longest stick insect is *Phobaeticus chani* at 567mm long

PHOTO: GETTY, THINKSTOCK X2, NASA/HUBBLE SPACE TELESCOPE, PRESS ASSOCIATION, REX

A French Rafale jet refuelling over Paris

Q **CARL COHEN**, DUBLIN

What's the lowest a plane can refuel in mid-air?

A REFUELLING AT ALTITUDES as low as 300m (1,000ft) has been examined as a strategy to keep strike planes below the enemy radar horizon. But it's much more dangerous if the refuelling plane needs to disengage suddenly. Tanker planes aren't very manoeuvrable, so this task is almost always performed above 6,000m (20,000ft). **LV**

Q **MIA CORLESS**, FRANCE

Can the human voice reach a pitch that is inaudible to the human ear?

A NO. THE MAXIMUM human vocal range runs from 60-7,000Hz, comfortably inside the normal hearing range of 20–20,000Hz. The reason we have evolved ears with a wider range than our voice is to help locate the direction a sound is coming from. A sound coming from one side of you will have a different frequency profile at your right and left ear, because your head absorbs some frequencies better than others. The effect is most pronounced at very high frequencies, so we have evolved high-frequency hearing to exploit this. Dogs have smaller heads than us so they need even higher frequency hearing for this direction finding to work. **LV**

High frequencies help us detect where sounds are coming from

Q **ROSIE WILLIS**, CUMBRIA

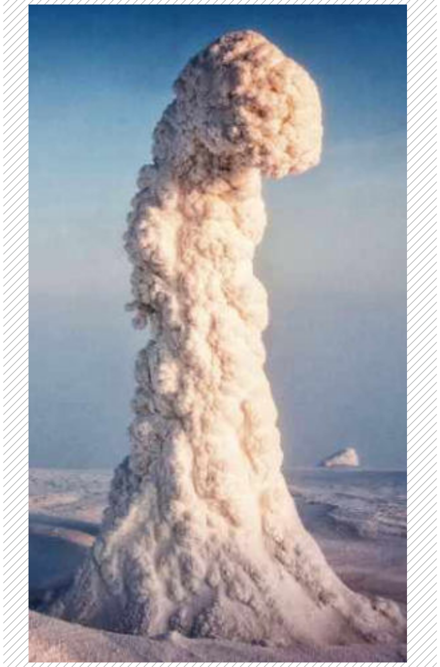
What determines life span?

A HUMANS LIVE FOR about 80 years, mice only a few years, some insects only a day, and what determines these life spans has long been debated. The 19th Century theory of 'programmed death' suggested there were evolutionary advantages to older individuals dying because they leave more space and food for youngsters.

This theory is now generally rejected in favour of two other theories. 'Mutation accumulation theory' builds on the idea that mutations which cause an animal to die when very young are weeded out by natural selection, while those which cause older animals to die accumulate, leaving older animals more susceptible to dying.

Finally, according to antagonistic pleiotropy theory, mutations that are beneficial when you're young could also be harmful if they act later in life, which ultimately influences life span. For instance, a mutation that results in rapid cell growth might help you heal faster, but could increase the risk of cancer later on. **SB**

WHAT IS THIS?



KNOW THE ANSWER?
Go to **sciencefocus.com/qanda/what** and submit your answer now!

LAST MONTH'S ANSWER:
The surface of the human tongue; well done Akmal Bakhronov

Q **MATT BURGESS**, LONDON

Will humans always continue to break athletic records?

A THE 'PUREST' OLYMPIC sports, such as running, swimming and jumping, are restricted by our anatomy. The 100m sprint record will probably never drop below 8.99 seconds, because the forces required would rip your tendons from your bones, and evolution is unlikely to change our bodies enough to bypass these limits. But Paralympians with ever more sophisticated 'bionic' legs will probably break able-bodied records one day, while new sports will no doubt be invented with new records for us to break. **LV**

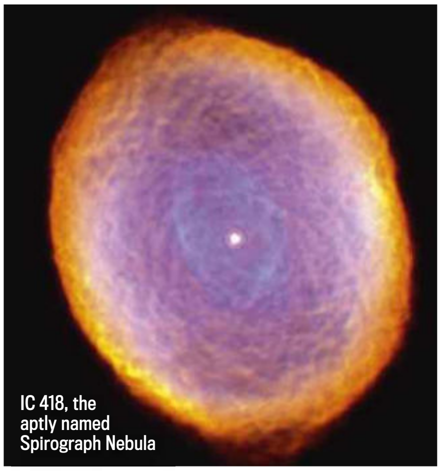
Did you know?
In 2011, a human kidney cell was made to emit green laser light by injecting it with jellyfish DNA.

Q **BARRY DISNEY**, SURREY

If a hole was drilled through the Earth, what would happen to a ball dropped into it?

A THE USUAL ANSWER to this 'thought experiment' says the ball would accelerate under gravity, reaching a speed of over 28,000km/h at the Earth's centre before rising back up to the surface on the opposite side of the Earth, arriving some 42 minutes after release. It would then fall back again and repeat the journey endlessly. But this ignores Earth's rotation. In 2004, mathematician Dr Andrew Simoson of King College, Tennessee, published an analysis of the problem showing that as the ball falls through the Earth, the force of gravity gets weaker towards the centre. Given that the speed of rotation of the Earth decreases with depth, the tunnel through which the ball travels would need to be curved to ensure the ball falls without hitting the sides.

Dr Simoson believes his calculations may explain the bizarre appearance of the Spirograph Nebula, found by the Hubble Space Telescope in 1999. Debris in this cosmic cloud feels gravity in the same way as the dropped ball, which may explain its strange curved lines. **RM**

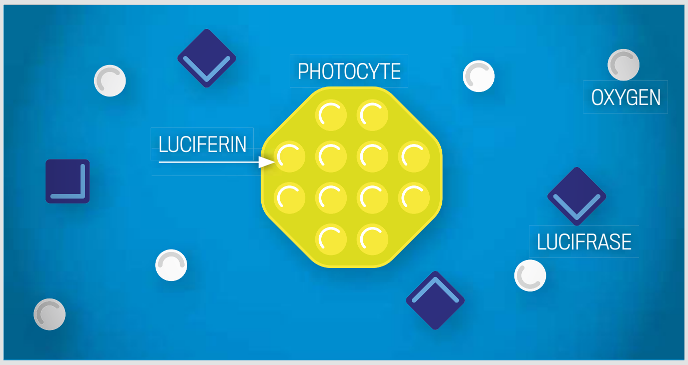


IC 418, the aptly named Spirograph Nebula

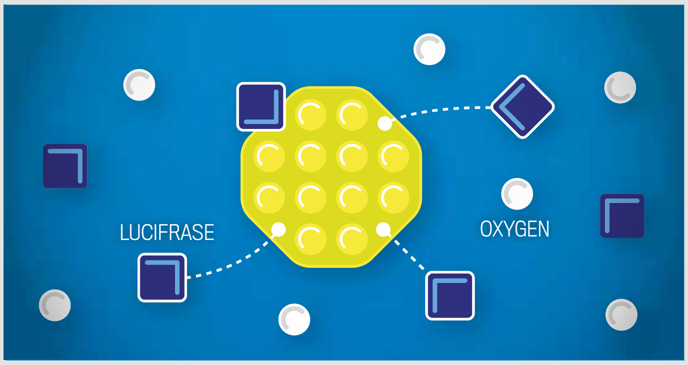
HOW IT WORKS

BIOLUMINESCENCE

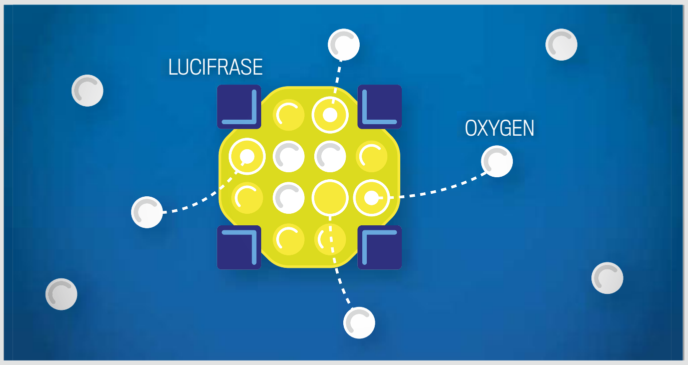
ORGANISMS THAT GLOW have specialised cells called photocytes that act as their light source. The location of these photocytes depends on the organism. In the case of the cockroach *Lucihormetica luckae* (pictured bottom), the photocytes are located in its head and abdomen, allowing these areas to glow. Within the photocytes, light-producing chemical reactions occur – as shown in the illustrations below.



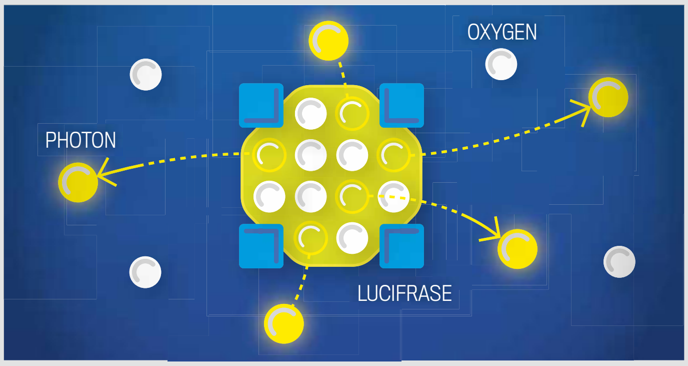
1. Light from the photocyte cells comes from the molecule **luciferin**



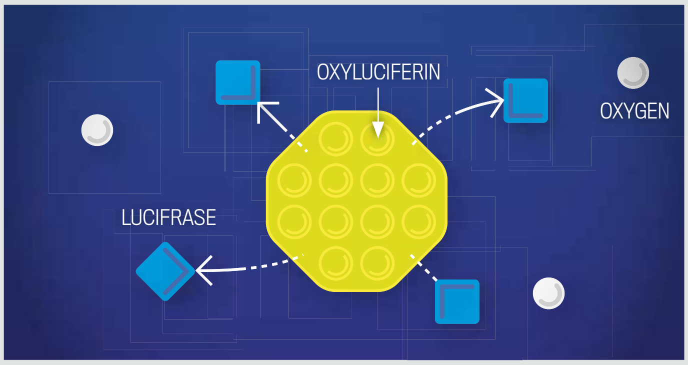
2. The light-producing chemical reaction is driven by the enzyme **luciferase**



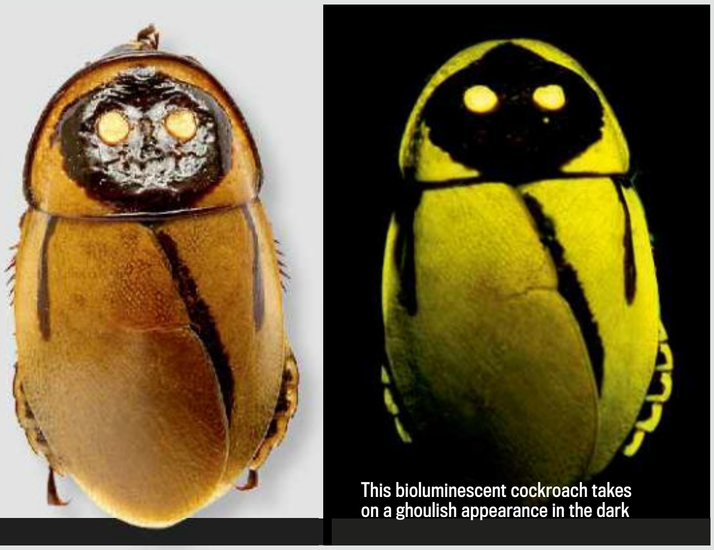
3. Luciferase is the catalyst for a reaction that combines luciferin with **oxygen**



4. Bioluminescence results from a reaction that generates **photons of light**



5. After the reaction, the oxidised luciferin becomes inactive **oxyluciferin**



This bioluminescent cockroach takes on a ghoulish appearance in the dark

ILLUSTRATOR: INFOMEN

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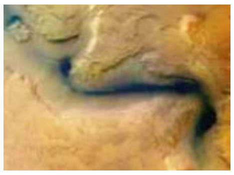
Q JOHN CROFT, HEREFORD

Could water exist elsewhere in the Solar System?


This Martian valley was probably created by a river

A EARTH IS the only planet with large quantities of running water, though some scientists claim that Mars may harbour substantial quantities. Earlier this year, a team led by Francis McCubbin of the University of New Mexico reported finding so-called hydrated compounds in meteorites known to have come from Mars. They argue such compounds support the existence of huge quantities of water locked up in rocks beneath its surface. NASA's new Curiosity rover may reveal the full story. **RM**

Q RICHARD O'NEILL, GLASGOW

Could molten lava be made in the lab?

A WITH A TEMPERATURE of 1,000°C, lava is pretty nasty stuff, but geologists have recreated it in the lab. In 1993, a team at the Massachusetts Institute of Technology created lava by reheating real samples under the conditions of intense temperature and pressure found inside volcanoes. But most researchers investigating lava prefer to use materials that have the requisite stickiness and density at room temperature. They include the waxy substance polyethylene glycol – best known for its use in lava lamps. **RM**

Scientists at MIT have managed to reheat lava in the lab, but most studies use analogues

Did you know?

The loudest siren ever was the Chrysler air raid siren of the 1950s Cold War era. It produced 138dB of sound at 30m.

Q EDDIE MANE, ABERDEEN

How do animals know where to migrate to?

Every year, Christmas Island's 50 million red crabs migrate to the sea to lay their eggs

A SOME BIRDS, FISH, turtles and whales travel enormous distances when migrating to find food or to mate. The furthest may be the bar-tailed godwit, flying over 10,000km from New Zealand to Alaska. Starlings use a Sun compass, which means knowing the time so as to compensate for the Sun's changing position. By contrast, mallards can find north using the stars, an ability that is genetically programmed. Many other birds as well as salamanders, salmon and hamsters use the earth's magnetic field. Loggerhead turtles can even sense the direction and strength of Earth's magnetic field soon after hatching and later use this skill to navigate along their regular migration route. Other animals use land features such as mountain ranges and rivers, and dolphins use the shape of the ocean floor. Wildebeest follow the scent of rain and salmon use smell to return to the very same stream where they were born. **SB**

Q ANDREW EVERSETT, DEVON

How are images captured of our galaxy?

A WE CANNOT CAPTURE a full image of our galaxy, the Milky Way, because we reside within it. But we can make whole-sky maps of the heavens which show our view of it. Long exposures are taken through large telescopes at dark sites, to record light from even the faintest of objects. These images can then be stitched together to form a two-dimensional view of the entire sky. **AG**

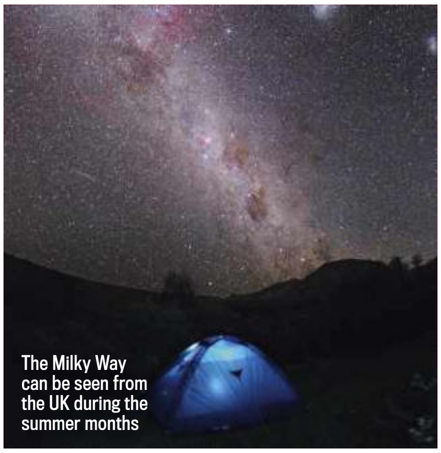

The Milky Way can be seen from the UK during the summer months

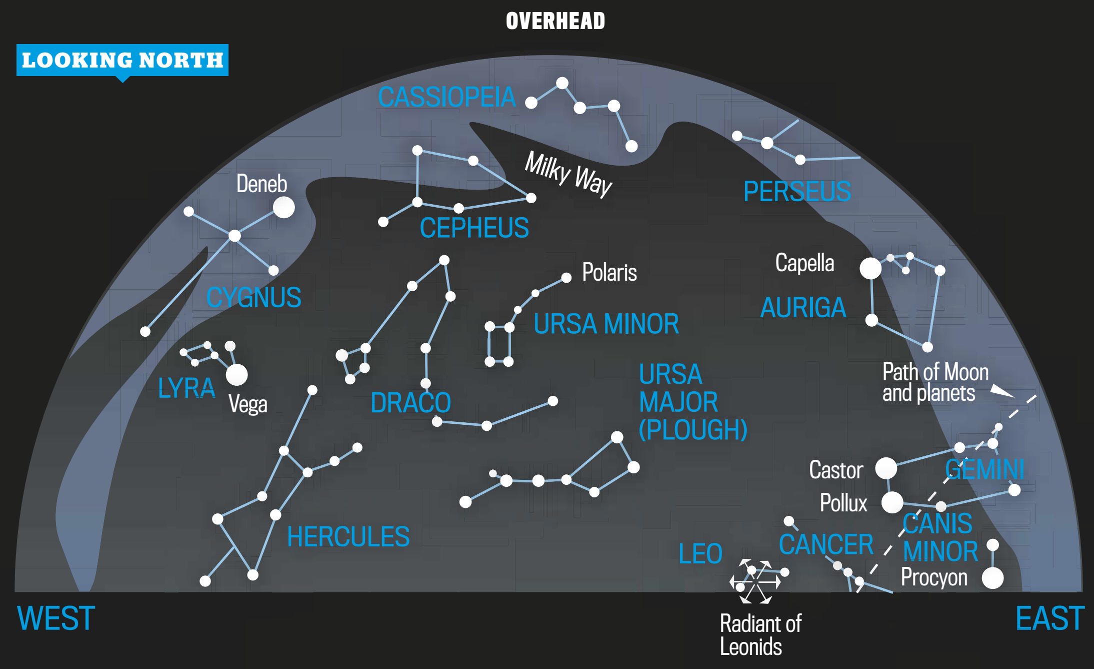
PHOTO: NASA, INGO ARNDT/FLPA, SUPERSTOCK, THINKSTOCK

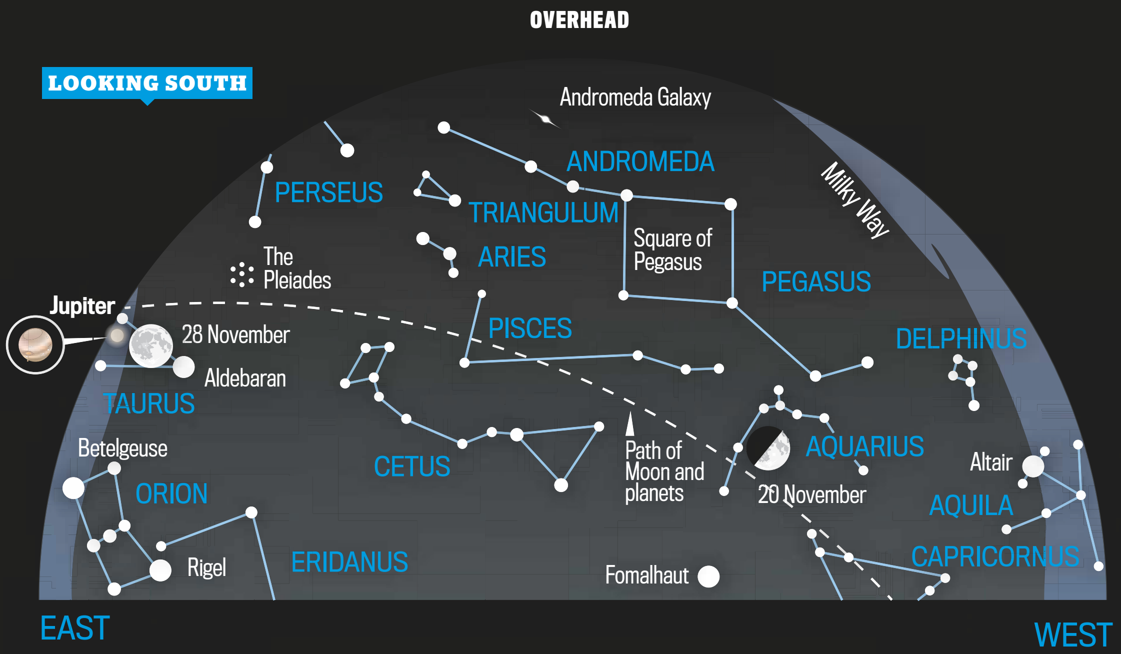
THE NIGHT SKY: WHAT CAN I SEE IN NOVEMBER?

Don't miss *The Sky at Night* on BBC One every month www.bbc.co.uk/skyatnight

Astronomy with Heather Couper and Nigel Henbest

If you're lucky enough to be in Queensland on 14 November (Australian time), you'll be able to catch a total eclipse of the Sun. This amazing spectacle lasts for about two minutes in Cairns, just after sunrise. There's nothing in the heavens like a total eclipse: before it you'll see an ethereal silvery light and, during totality, the majestic outer atmosphere of the Sun, the corona. But even if you're stuck in the UK, there's still plenty going on in the skies to grab your attention!





LOOKING NORTH

All month, all night
The Northern Lights (aurorae) colour the sky red, green and yellow as electrically charged particles from the Sun, which is currently hotting up its activity, zap the Earth's atmosphere. Best seen from northern Britain.

16-17 November, after 12am
Tonight marks the peak of the Leonid meteors, which appear to 'radiate' from the constellation of Leo. These shooting stars are fragments of dust from comet Tempel-Tuttle. Look northeast, and you may see 20 meteors per hour.

All month, all night
Polaris, the Pole Star, happens to lie 'above' the Earth's north pole, so it's always due north. Marking the tail of the Little Bear (Ursa Minor), this iconic star is surprisingly faint.

LOOKING SOUTH

All month, late evening
Use the barren Square of Pegasus as a test of light pollution. Count the number of stars you can see *inside* the Square. In a city it's probably zero, but in dark country skies it can reach a dozen or more.

All month, midnight
Winter is truly on its way when you spot the Pleiades star cluster. The famed seven stars are the brightest of some 1,000 blue-white stars born 100 million years ago.

27 November, 5.30am
Venus and Saturn are almost touching in the morning sky. It's a great sight for the naked eye, and a fantastic photo opportunity.

Find out more
Sky at Night Magazine
On sale now, priced £4.75

Q **RH GILLINGWATER**, READING

Why do many planes have tipped wings?

A THE STRUCTURES THAT sweep upwards on aircraft wings are called winglets. Wings have a curved cross section and lift is formed by the pressure difference between the air flowing over the top and that underneath. Air travels faster over the curved top and thus is lower in pressure than on the underside. But at the tips, air from underneath tries to flow up and over the wing, reducing lift. The winglet blocks that effect, and reduces drag by preventing vortices from forming as the tapered wingtips cut through the air. Planes like the Airbus A320 have winglets. They are also common on business jets: increased lift allows a shorter take-off, enabling the jets to get in and out of smaller airfields. **GM**

The sheer size of the Universe means there are likely to be other civilisations out there

Q **KEVIN HOLMES**, BY EMAIL

How likely is it that other planets have intelligent life?

A THE SOLUTION TO this important question involves many factors from the biological and physical sciences, and as yet scientists are unsure of the answer. We know that life began on Earth very soon after our planet's formation, and that the basic chemical components of life could be synthesized in the primitive Earth's environment. We have also concluded that Earth-like planets may well be common in the Universe. So, although there is a huge amount needed to fill in the gaps, this implies that life itself should also be common in the Universe.

This doesn't mean that all life is destined to become 'intelligent': we have no real idea about what factors are involved in the emergence of 'intelligent' life, or about the longevity of possible extra-terrestrial civilisations. But most scientists would agree that the Universe is so big, and so full of stuff, that the weight of numbers means it's almost a certainty that we're not the only intelligent life form in the Universe.

Whether we will ever discover, or be able to communicate with, these other life forms is another question entirely. **AG**

Did you know?

The shortfin mako shark can leap up to 6m out of the water – that's the highest 'breach' of any shark species.

Q **JR KEENAN**, BY EMAIL

How does the Dyson bladeless fan work?

A THE DYSON FAN has blades inside its base that draw in about 27 litres of air per second, and pass it through the circular tube mounted on top. In the rim of the tube is a thin foil that sucks in more air. This creates a multiplier effect, with more and more air passing through the ring. The effect is boosted by a process called 'entrainment', whereby air near the edges of the fan is also swept into the stream. The result is a device that creates, Dyson claims, an air output 15 times that of a conventional fan. **GM**

Q **JOHN MITCHELL**, GLASGOW

How do bath bombs work?

Bath bombs – an explosive way to create the perfect bath

A THE PART that makes them fizz is the same as an Alka Seltzer or soluble aspirin tablet: sodium bicarbonate and citric acid. These chemicals are inert when they are dry powders, but in water they dissolve and the citric acid reacts with the sodium bicarbonate to form sodium citrate and carbon dioxide. The sodium citrate stays in solution and you don't really notice it, but the carbon dioxide bubbles out as a gas that helps the bath bomb break up. This lets the detergents, perfumes and oils that make up the rest of the bath bomb mix with the bathwater. **LV**

NEXT MONTH Over 30 more of your questions answered

For more answers to the most puzzling questions, see the Q&A archive at **www.sciencefocus/qanda**

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HOW DO WE KNOW?

THE SPEED OF LIGHT

BY PROF FRANK CLOSE

It's the universal speed limit and the key to making sense of the Cosmos, but how did scientists discover how fast light can travel?

ANCIENT GREEK mathematician Euclid believed that sight occurs because the eye emits light. Hero of Alexandria pronounced that light must travel at infinite speed as distant stars appear at the instant one's eyes open. And in the 11th Century, the Basran mathematician Alhazen wrote his *Book Of Optics*, which has been compared to Newton's *Principia Mathematica* in importance. In it, he argued that light moves from object to eye, with a finite speed that varies depending on the medium through which it passes. Light moves more slowly through water and glass than it does through air.

Alhazen's *Book Of Optics*, a key medieval science text

PHOTO: ADILNOR COLLECTION, THINKSTOCK

Ideas continued to flow. In the 13th Century, Roger Bacon used the ideas of Alhazen to support the idea that light travels at a very high speed, faster than sound but finite. The possibility that light travels infinitely fast in empty space, but slows down in a medium, was also believed at that time.

As late as the 17th Century, luminaries such as Kepler and Descartes insisted that light travels infinitely fast. Kepler argued that this must be so, as empty space would offer no resistance to its passage. Descartes based his arguments on observation: during a lunar eclipse the Sun, Earth, and Moon would be noticeably out of alignment if light travelled at a finite speed, and the absence of such misalignment convinced him that light travels instantaneously.

It was around this time that the first attempts to make a direct measurement were made. In 1629, the Dutch philosopher Isaac Beeckman proposed an experiment wherein the flash of a cannon was reflected by a mirror, about a mile away, and the time lapse measured. Galileo independently proposed a similar experiment, involving the uncovering of a lit lantern, which was carried out by his students in 1667. No time delay was detected, confirming the prejudice that light travels infinitely fast.

With our modern knowledge of light's speed, we know it would have taken about one hundred-thousandth of a second for it to

> IN A NUTSHELL

How fast light can travel is a question that scientific minds have been grappling with since ancient Greece. Today we can measure the speed of light very precisely but, as this article explains, it took hundreds of years and lots of theories to get to where we are now.

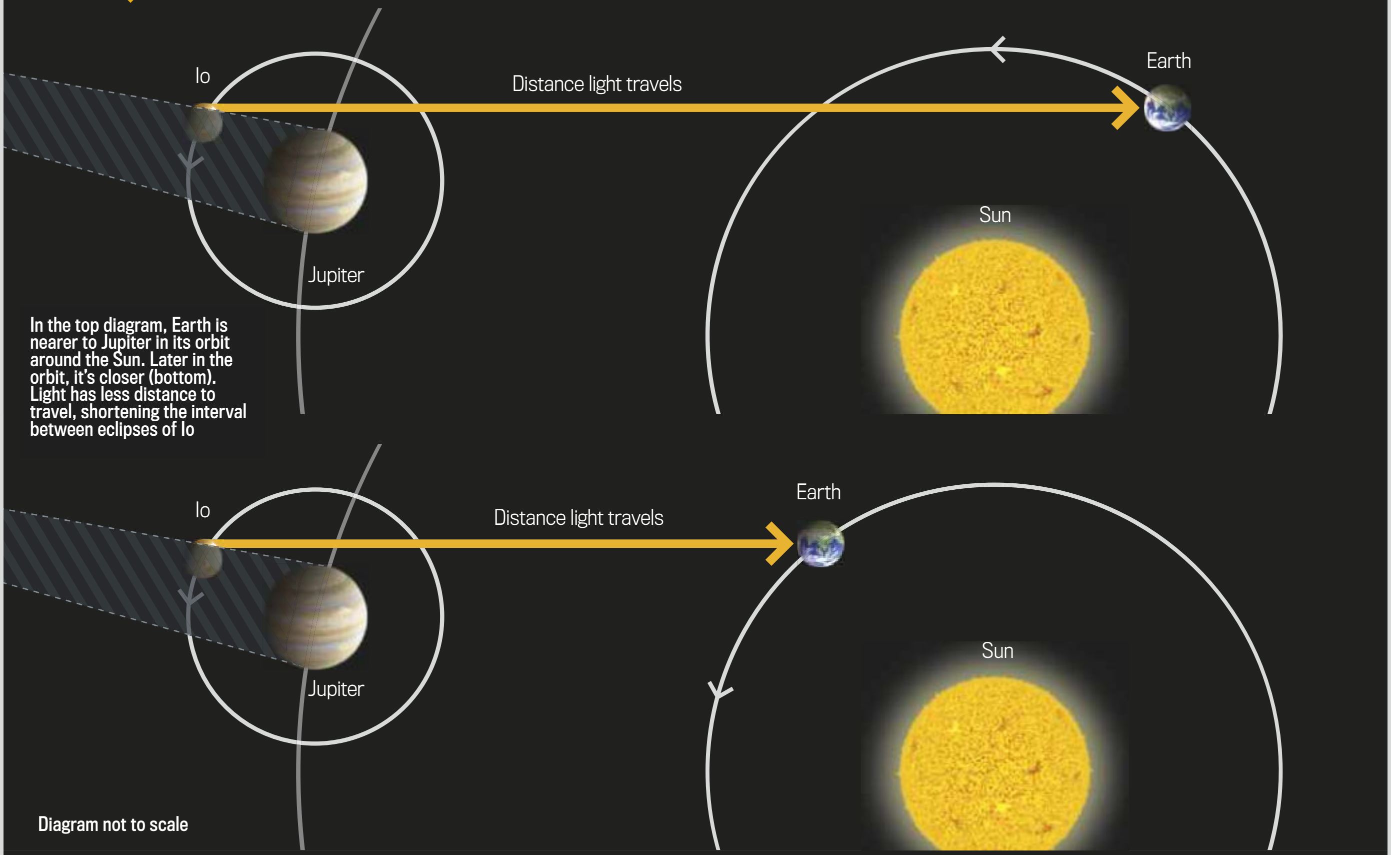
Accompanies Dara O Briain's new science series on BBC Two make the round trip. That's less than the reaction time of the observers, hence their inability to measure any delay – the distances involved were simply too small. By contrast, the distances between the planets are so large that light takes several minutes to travel between them. All you need is some reference against which events can be measured.

In Paris, Giovanni Cassini had been observing the moons of Jupiter, which in their orbits disappear behind the planet and reappear later. His measurements varied, and he attributed this to light having a finite speed. Danish astronomer Ole Rømer joined Cassini, and in 1676 noticed that the time that Io, Jupiter's innermost moon, takes to reappear is less when the Earth is approaching Jupiter than when it's receding from it. This confirmed Cassini's conjecture – when Earth is approaching Jupiter, it has moved nearer while the light is en route, and the total distance for the light to travel is less. Hence it arrives relatively early. Conversely, when we are travelling away, the light has to travel further and arrives relatively late. Rømer's measurements and his discovery of the correlation with Earth's motion cause him to be credited with the discovery. In 1690, Dutch mathematician Christiaan Huygens used this to estimate a speed for light of about 220,000km/s, about 70 per cent of the modern value.

The next step in the story again involves astronomy, and the aberration of light, which may be illustrated by a familiar phenomenon – keeping dry as you move through falling rain. Rain that is falling vertically when you are at rest appears to be falling

THE KEY EXPERIMENT

How observing the movement of the moons of Jupiter provided 17th Century astronomers Cassini, Rømer and Huygens with an early indication of the speed of light



In the top diagram, Earth is nearer to Jupiter in its orbit around the Sun. Later in the orbit, it's closer (bottom). Light has less distance to travel, shortening the interval between eclipses of Io

Diagram not to scale

Io, the innermost moon of Jupiter, orbits that planet every 42.5 hours. Viewed from Earth, Io periodically disappears behind Jupiter and reappears later. It was thought that the time between eclipses would be the same.

However, when Giovanni Cassini made measurements around the year 1671, the results kept changing. He had the insight that this could be due to light taking time to travel from Jupiter to Earth, during which period the Earth had moved. Therefore the distance travelled from Jupiter to Cassini's telescope would vary from one eclipse to another, depending on whether the Earth was moving towards or away from Jupiter.

Strangely, Cassini seems not to have trusted his intuition, and his assistant, Ole Rømer, performed his own measurements. When these were combined with Cassini's, Rømer realised that the variations correlated with the relative motion of Earth and Jupiter. He made a long series of measurements, which established this, and which led to an estimate of light's speed to be over 220,000km/s. For many, this was so unimaginably fast as to be regarded as infinite, and Rømer's ideas were not universally believed.

It was not until James Bradley measured the speed of light by means of stellar aberration that Rømer's theory was accepted.

PHOTO: SCIENCE AND SCOIETY PICTURE LIBRARY, THINKSTOCK, ALAMY, SCIENCE PHOTO LIBRARY, CORBIS ILLUSTRATOR: RICHARDPALMERGRAPHICS.COM

from a point in front of you as you walk forwards – you have to tip your umbrella to keep dry. Walk in the opposite direction and the origin of the raindrops now also appears to be in the opposite direction. Now think of the falling rain as light travelling from a distant star, and your motion being that of the Earth through the heavens. The apparent position of a star varies during the year due to this phenomenon, known as aberration.

James Bradley, the Astronomer Royal, discovered this phenomenon in 1729. He made measurements of a star in the constellation Draco, and found that its position moved first south and then north on a six-month cycle. The motion was little more than 1/100th of a degree, but this could be seen easily enough with 18th Century equipment. From this, Bradley deduced that light travels about 10,200 times faster than the Earth in its orbit, 295,000km/s, an estimate that is within about 2 per cent of the modern value.

BACK DOWN TO EARTH

To determine high speed requires either accessing a large distance, as in astronomy, or the ability to measure very small time intervals. The French physicist Louis Fizeau in 1849 found a way to do this on Earth.

He shone light between the teeth of a rapidly rotating wheel. A mirror five miles away reflected the light back. If the light passed through a gap, it would be seen, but if it hit a tooth between gaps, darkness would ensue. He varied the speed of rotation and from this was able to determine how long the light had taken to make the round trip. Knowing the distance to the remote mirror, he was able to infer the speed, some 313,000km/s. In 1862, Leon Foucault used a similar idea, but with rotating mirrors to determine the angle through which the light had been deflected. He found a speed of 299,796km/s, which is remarkably close to the modern value of 299,792.46km/s.

In 1865 James Clerk Maxwell published his work on electromagnetic waves, in which light is a wave of electric and magnetic fields. In any electromagnetic wave, an electric field disappears and a magnetic field emerges, and vice versa, over and over. The resistance or ‘stiffness’ of free space to the former is called its electric

➔

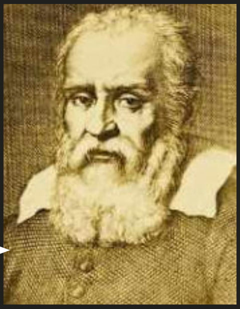
CAST OF CHARACTERS

Some of the great minds that pondered the speed of light through the ages

Alhazen

(964-1040)

Based in Cairo, the Basra-born mathematician wrote the seven-volume *Book Of Optics* from 1011-1020. This was translated into Latin in the 12th Century, and influenced western thought regarding the rainbow and optics in general. This inspired Roger Bacon (1214-1294), an English philosopher who is often wrongly credited for Alhazen’s ideas.



Galileo Galilei

(1564 -1642)

Often regarded as the father of modern science, the Italian polymath’s work led to the theory of mechanics. He also made improvements to the telescope and founded observational astronomy. He proposed that the planets orbit the Sun, which is at the centre of the Solar System.

Ole Rømer

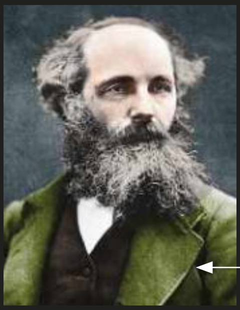
(1644-1710)

During his time as assistant to Giovanni Cassini (1625-1712) in Paris, the Danish astronomer observed the moons of Jupiter. Although Cassini had the idea that the data showed that light travels at finite speed, it was Rømer who demonstrated this.

Leon Foucault

(1819- 1868)

In addition to his work on the speed of light, including showing that it travels more slowly through water than through air, the French physicist is known for the Foucault pendulum. This offers a practical way of seeing the effects of Earth’s rotation.



James Clerk Maxwell

(1831-1879)

The Scotsman is credited with uniting all known phenomena of electricity and magnetism in a theory that predicted the existence of electromagnetic waves. The speed of these waves agreed with that of light. This established light, radio waves, x-rays and more as all being electromagnetic waves that differ in frequency and wavelength.

TIMELINE

How scientists spent 300 years devising ever more accurate ways of measuring the speed of light

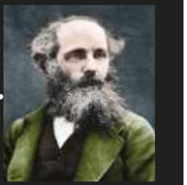
1690

After Ole Rømer shows that light travels at a finite speed, fellow Dane **Christiaan Huygens** calculates this speed to be around 220,000km/s.

1862

French physicist **Léon Foucault** uses rotating mirrors to calculate the speed of light at 299,796km/s.

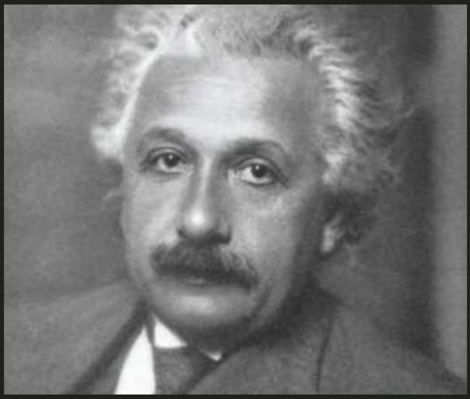
1865



James Maxwell shows light to be an electromagnetic wave, enabling its speed to be calculated from known properties of space.

1905

The concept that the speed of light is universal, independent of the speed of the source or of the observer, forms the basis of the Special Theory of Relativity developed by **Albert Einstein** (pictured).



1972

A laser (right) is used to measure the frequency of a particular spectral line of a **krypton atom**. By combining this information with the definition of the metre, the speed of light in a vacuum is measured to a precision of one part in a billion: 299,792,458m/s, to an accuracy of 1m/s.

1983

Light speed made absolute at the **17th General Conference on Weights and Measures**. As a result, a metre is now defined as 1/299,792,458th the distance travelled by light in a vacuum in one second.

PHOTO: BRIDGEMAN ART LIBRARY, GETTY, NIST, SCIENCE PHOTO LIBRARY

permittivity, while its resistance to the magnetic field is called its magnetic permeability. In Maxwell's theory, the speed of light is related to these quantities. The ease with which the electric and magnetic fields can oscillate back and forth determine the speed at which the electromagnetic wave travels. It turns out that the product of these quantities is proportional to the inverse of the square of the speed of light.

So in a sense Kepler was right, centuries ago. If space offered no resistance – in Maxwell's theory, if the electric or magnetic 'stiffness' were zero – the speed of light would indeed be infinite. But in reality, the electric and magnetic 'stiffness' are *not* zero, and when their values were inserted into Maxwell's equations at the end of the 19th Century, they gave a value of 299,788km/s, then the most accurate estimate of the speed of light available.

ONWARDS TO EINSTEIN

In 1887, Albert Michelson and Edward Morley in the USA attempted to measure the speed of the Earth through the 'ether' – a medium then believed to permeate all space – by measuring the difference in the speed of light in two perpendicular directions. They used semi-transparent mirrors, which deflected light through 90° while also allowing some to carry on unhindered. By reflecting the two beams back along their paths and recombining them, any difference in speed would show up by the two waves being out of phase – a mismatch between their peaks and troughs which would show up as a subtle set of dark and light fringes, known as an interference pattern.

Michelson and Morley's setup proved highly sensitive and, to their surprise, demonstrated that the speed of light is universal, independent of direction. In turn, this led Einstein to insist that the ether does not exist (at least in the form then believed), and to propose his theory of Special Relativity in 1905. Thus precise measurements of the speed of light had led to profound new insights into the nature of space and time, courtesy of Einstein.

In particular, Einstein's theory implies that the speed of light in a vacuum is nature's speed limit: no object that has mass can ever attain the speed of light in a vacuum, while any particles that have *no* mass must travel

NEED TO KNOW

Five key scientific terms to help you understand light

1 Aberration of light

An optical phenomenon whereby a star appears to move about its true position. It is a result of the finite speed of light and the motion of the Earth.

2 Atomic clock

This is the most accurate way of measuring time we have. It uses the frequency of microwave signals that electrons in atoms emit when they change energy levels.

3 Cavity resonator

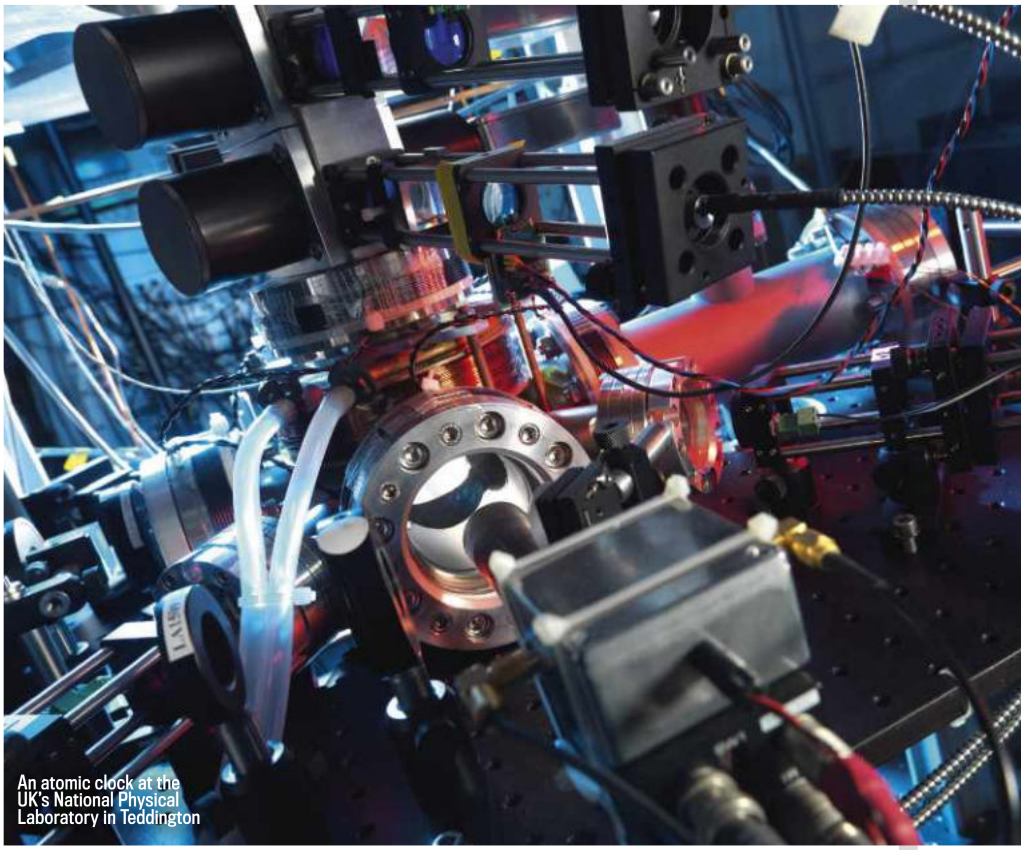
This is a hollow conductor blocked at both ends, along which an electromagnetic wave can travel and be reflected back and forth. In a resonator of the correct length, a wave of a given frequency will be amplified.

4 Electric permittivity

An electric charge gives rise to an electric field. The resistance to forming this electric field is known as the electric permittivity. It can be determined using capacitors, which are devices for storing electric charge.

5 Magnetic permeability

The measure of how easily a substance, including empty space, becomes magnetized. The product of magnetic permeability and electric permittivity equals the inverse of the square of the speed of light.



An atomic clock at the UK's National Physical Laboratory in Teddington

through a vacuum at this universal speed. However, light is slowed when it passes through a transparent medium, such as water or glass; it is possible for particles such as an electron to travel through the medium faster than light, but still below the absolute speed limit.

Before the invention of the laser, independent measurements of the frequency and wavelengths of electromagnetic waves were made in the 1950s using 'cavity resonators', which gave a value of 299,792km/s. with an uncertainty of 3km/s. A modern demonstration is to put a chocolate bar in a microwave oven. Remove the turntable so the specimen is stationary, and it will cook fastest at the points where the waves are most intense. The distance between two successive spots is half the wavelength of the microwaves. Multiply the wavelength by the microwave frequency (typically 2,450MHz, but check with your manual!) and the speed of light results, though with less accuracy than in the 1950s laboratory!

Modern large-length experiments involve sending radio signals to different spacecraft whose positions in the Solar System have been precisely calculated, allowing for the gravity of the Sun and planets. This enables the speed of light to be calculated to an accuracy of 20 parts per trillion.

Modern descendents of the Michelson-Morley technique use a laser beam, whose frequency is known very precisely. After the beam is split into two paths and then recombined, the interference pattern can be decoded to determine the wavelength of the light. The speed is then the product of this wavelength and the frequency. In 1972, this led to a precision in the measurement of the speed of better than four parts per billion.

Today, advanced highly stable lasers, and the measurement of time intervals using atomic clocks, enable the most accurate value of 299,792,458m/s, with an uncertainty of just 1m/s. The second can be defined precisely using atomic clocks, and the uncertainty in the speed of light is dominated by the accuracy in defining a metre.

Consequently, since 1983 it has been agreed to 'fix' the speed of light at the above value, and to define the metre so that there are exactly 299,792,458 of them in the distance that light travels in a vacuum in one second. So today, instead of measuring the speed of light relative to the space-time of the Universe, as physicists struggled to do for centuries, we determine the latter from the speed of light. ■

FRANK CLOSE is a Professor of Physics at the University of Oxford and the author of *The Infinity Puzzle* (OUP, £16.99)

Find out more

On **Dara O Briain's** new science series, Dr Mark Miodownik measures the speed of light in the studio. See p103

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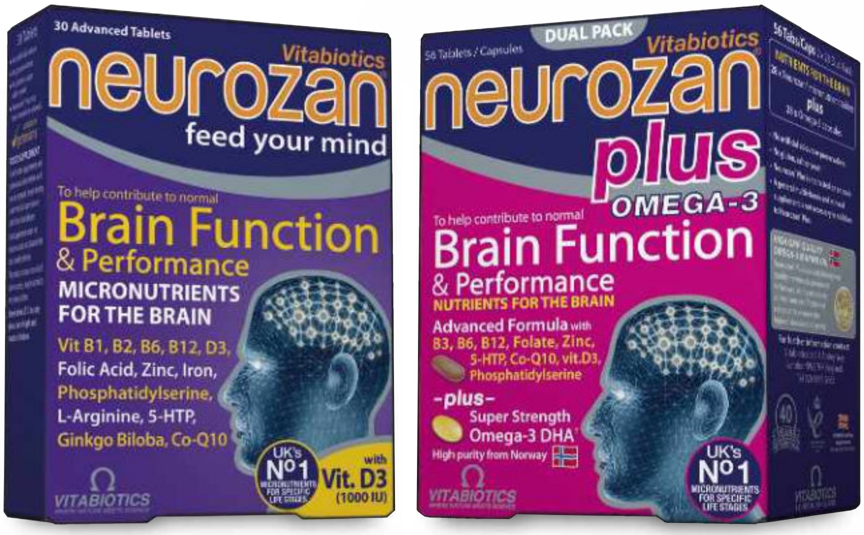
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TO DO LIST

PLAN YOUR MONTH AHEAD WITH OUR EXPERT GUIDE

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PICK OF THE MONTH

New stars of science

Mock The Week star Dara O Briain is joined on his new show by, from left to right: James May, Helen Czerski and Mark Miodownik

YOU JUST CAN'T keep that Dara O Briain away from science. This time he's the anchor of a new magazine-style BBC show. As-yet untitled, the new series brings guest presenters and experiments in front of a studio audience, along with films on current and classic research. Think *Stargazing Live*, but opened up to all aspects of science.

Some of the team are experts in their own right. To guide us through the advances in engineering and technology there's *Materials* scientist Mark Miodownik. While every week physicist Dr Helen Czerski and neuroscientist Dr Tali Sharot will visit labs at the cutting edge of research. And in the studio, guests will include scientists at the pinnacle of their respective fields.

There'll be other familiar faces from the world of entertainment too. James May will be sent off to learn something new, while Mark Steel presents his bluffer's guide to science. Then, just to check they listened to what they were learning on location, they'll be coming into the studio to talk about what they found out.

But this isn't just *Blue Peter* for grown-ups. You can also expect regular contributions from science journalist Alok Jha on the burning controversies in the news, as well as a round-up of the latest discoveries.

Add participation from the studio audience, Dara O Briain's relaxed authority, and a whiff of live TV anarchy, and we're hoping for a truly fresh look at science for the adult viewer.

BBC TWO

Dara O Briain's new show airs in early November on BBC Two. See radiotimes.com for times

ILLUSTRATION: GLUEKIT

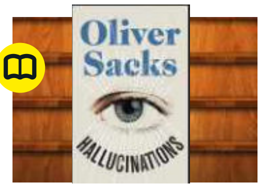
DON'T MISS!

Manchester Science Festival

With exhibits and talks, the streets and venues of Manchester host a celebration of science. **p104**

Assassin's Creed III

The series that gives history a sci-fi twist returns for an ambitious take on the American Civil War. **p109**



Hallucinations

With personal experience, neurologist Oliver Sacks delves into the science behind sensory delusions in his new book. **p110**

VISIT

EVENTS & EXHIBITIONS

WITH JHENI OSMAN

26 OCT - 18 JAN

Game

Science Gallery, Dublin, free, www.sciencegallery.com

THE GAMING INDUSTRY has overtaken all other forms of entertainment, with global sales predicted to reach £43 billion this year. It's hardly surprising as the average 23-year-old gamer in the UK spends 11 hours a week on their hobby. So what does the future hold? What's the next Kinect? Where will mobile apps go? How will augmented reality evolve? This exhibition investigates the gradual merging of reality and virtual reality, and the future of gaming.

29 OCTOBER

Café Scientifique

Tobacco Factory, Bristol, 8pm-10pm, free, bit.ly/Q129Jf

IN HIS 1943 book *Le Voyageur Imprudent*, science fiction writer René Barjavel first described the so-called 'grandfather paradox', which asks whether a time traveller going back in time to kill his grandfather before he met his grandmother would mean the time traveller would never be born. In this talk John Rarity, Professor of Optical Communication Systems, will explain how his photonic time machine might illustrate the grandfather paradox.

31 OCTOBER

The Terror Tour

Natural History Museum, London, 7pm-10pm, £28, www.nhm.ac.uk/night-safari

FORGET FANCY DRESS parties, graveyards or disused mortuaries… the spookiest place to hang out this Halloween is at the Natural History Museum. On this tour led by five scientists who work on-site, you'll discover the creepiest, scariest, most terrifying specimens that lurk in the depths of the museum. It doesn't actually say anything about fancy dress, but if you do decide to turn up dressed as Dracula we're sure they won't mind.

JHENI OSMAN is a science writer and the author of *100 Ideas That Changed The World* (BBC Books, £9.99)

Catalytic Clothing
Field of Jeans
by artist/designer Professor Helen Storey
and scientist Professor Tony Ryan
Please Do Not Touch

Air-purifying jeans are among the delights Manchester Science Festival has to offer

EDITOR'S CHOICE

27 OCT - 4 NOV

Manchester Science Festival

Greater Manchester, various locations and prices, see www.manchestersciencefestival.com for full details

➔ WITH 2012'S ABORTIVE 'summer' becoming a distant memory, you might be forgiven for thinking there are no more festivals left to go to. Not so, as Manchester's streets, museums and venues get taken over by scientists and entertainers for a week-long celebration of science.

Highlights include Robot Hackday, where you rip apart old electronic junk before reassembling it into a robot; the Electric Tea Party, which invites girl geeks to make LED badges while munching on cake; and the Turing Project, where wannabe secret agents can help safeguard an emergency communication channel. There are debates to join on topics such as whether the internet should be better regulated, or whether you'd eat an insect. And you can catch stand-up shows like 'Festival Of The Spoken Nerd', where comedians and scientists blend comedy, science, music and interactive experiments to answer important questions like 'How does the angler fish have sex?'.

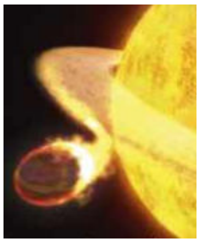
Events take place at MOSI and all over Greater Manchester – at Jodrell Bank you can quiz astronomers and engineers about all things space-related. Some events even roam the streets – hop inside a camper van cinema to take a trip through space and time while eating popcorn.

PHOTO: NASA, UNIVERSITY OF STRATHCLYDE, GETTY, ZSL, THINKSTOCK

5 NOVEMBER

Stars, Planets And The Possibilities Of Life

Phoenix Arts Centre, Exeter, 8.30pm, free, http://projects.exeter.ac.uk/cafescientifique



OVER 750 EXOPLANETS have been identified to date. These distant worlds often have strange characteristics – Kepler-7b has the density of a polystyrene cup, while gas giant WASP 12b may have a diamond core. In this talk, Exeter University's Fred Pont reveals how exoplanets are detected, and what they may tell us about the origins of life.

6 NOVEMBER

Pervasive Technologies

The Jekyll And Hyde, 28 Steelhouse Lane, Birmingham, 7pm, free, www.thinktank.ac/cafe_sci

SMART TECHNOLOGY IS starting to be embedded in everything around us, from T-shirts to walls. Take the case of 'smart paint', which turns buildings into carbon sinks. Join Birmingham University's Dr Ben Cowan for this pub-based lecture and find out how psychological research can be used to convince us of the benefits of implementing such eco-tech.

8 NOVEMBER

Noah's Ark: Animals Vs People

Wellcome Collection, London, 7pm-8.30pm, free, www.wellcomecollection.org/whats-on/calendar.aspx

WITH OVER SEVEN billion human beings all eating, breeding, travelling and consuming, how can we all stay healthy? In this talk, experts in infectious diseases, wildlife health and anthropology discuss how population growth, travel and livestock movement affect disease transmission, and explain the constant need for new models of prediction and prevention.

12 NOVEMBER

U3A Bioethics Day

Centre For Life, Newcastle, 9am-5pm, £15, www.life.org.uk/whats-on/events

AT THIS ONE-DAY event you'll be able to meet key academics involved in bioethics research and debate everything from assisted conception, life-sustaining technologies and stem-cell science to assisted suicide and euthanasia. Expect a thought-provoking day out. Note that this event is open to U3A members only – to join contact j.a.leiper121@btinternet.com.

SPEAKER OF THE MONTH

7 NOVEMBER

Caleb Scharf

Bristol Festival of Ideas, Watershed, 6pm, £6.50, www.ideasfestival.co.uk

Who is he?
As Director of Astrobiology at Columbia University, New York, Caleb Scharf spends his time searching the cosmos for planets that could harbour life. To identify which exoplanets could carry biological beings, Scharf catalogues each planet's formation, history and properties to see if it matches the ingredients for life as we know it.

What's he talking about?
Black holes are thought of as forces of destruction that swallow up everything within their grasp but, as Scharf explains, new research is showing that they spit out huge clouds of energy as well. These black hole 'bubbles' rearrange the cosmos around them, creating new celestial bodies. His new book, *Gravity's Engines*, is reviewed on p111.

UNTIL 16 NOV

LAST CHANCE TO SEE

Broadcasting Science

The Royal Society, London, until 16 November, free, royalsociety.org

THIS EXHIBITION DRAWS on the Royal Society's substantial archives to explore how science was addressed in the formative years of broadcast media, and looks at the early careers of renowned science broadcasters. On show are iconic items such as David Attenborough's Madagascan elephant bird egg, which he normally keeps under wraps in his cellar, and letters showing a spat between Sir Arthur Conan Doyle and scientist Sir James Jeans.

WATCH

TV, DVD & BLU-RAY

WITH TIMANDRA HARKNESS

FROM 21 OCT

When Animals Strike

Animal Planet, starts 21 October, 9pm

WHAT HAPPENS WHEN sloths stage a go-slow? Disgruntled dogs stage a walkies-out? Socialist worker bees demand shorter hours and more honey? No, you're right, this two-parter isn't about animals taking industrial action, it's about people being attacked by alligators, polar bears and wolves. One unlucky surfer faces two great white sharks and an unsuspecting cyclist is thrown off when she crosses a line. Oh sorry, no, a LION. She crosses the path of a mountain lion. Good viewing if you want an excuse for avoiding country walks.

NOVEMBER

Wild Things With Dominic Monaghan

Channel 5, November

YOU MIGHT RECOGNISE Monaghan from *Lord Of The Rings* and *Lost*, but in this eight-part series he goes after beasts far scarier than any Orc, mainly since this time they're real. I imagine a round-the-world trip to meet exotic wildlife must have sounded like a great job at first. But when that meant going into a toxic cave in Venezuela to meet a giant, venomous, flesh-eating centipede, the actor probably started to miss the days when the monsters were all CGI.

FROM 4 NOV

Curiosity

Discovery, starts 4 November, 10pm

THE SERIES THAT uses science to explore enduring mysteries is back, and the episode on brainwashing is brilliant. Among the riddles this time around are the mysterious Bermuda Triangle, where ships and even aeroplanes vanish into thin air. The episode on brainwashing is brilliant. Diving to examine the many shipwrecks in the Bermuda region, experts develop theories to test on real boats and planes. Another episode looks at Stonehenge, but don't miss the episode on brainwashing because it shows brilliantly how brainwashing could never work. Ever.

TIMANDRA HARKNESS is a BBC Radio 4 presenter and stand-up comic. Her latest show is 'Humans Vs Nature: Engineering FTW'

Even time travellers can get caught up in Bank Holiday tailbacks

FROM 22 NOV

How We Invented The World

Discovery, starts 22 November, 9pm

IF YOU HAD to choose just four inventions that define our age, what would they be? The Apollo space capsules perhaps? The contraceptive pill? The flushing lavatory? Pot noodles?

Well tough, because the makers of this four-part series have chosen their own four: the car, the aeroplane, the skyscraper and the mobile phone. Each episode takes one invention back to its origins, revealing the interplay of ingenuity, experimentation, collaboration and sheer luck that goes into such world-changing technologies.

Each of the four inventions chosen required much more than scientific understanding to come into being. Take the car: it doesn't just need four wheels and a motor, it requires a complex infrastructure of roads, refuelling stations, training and licensing, for a start. How did we get here from a point where automobiles were expensive and impractical toys, and the modern car was as inconceivable as the commercial jet?

But as engineering developed, it made possible social changes that would have been just as difficult to imagine: most UK families can now travel where and when they want, carrying their luggage, children, pets, personal selection of ill-chosen music and an old tin of barley sugar sweets with them.

In an even shorter time scale, the mobile telephone has transformed the way we lead our social lives. If you're under 25 you may find it hard to imagine teenage dating that depended on a landline phone, shared with your parents, who probably also provided your only message-taking service. You're right: it *is* a wonder anyone of your parents' generation ever got together.

PHOTO: CORBIS, DISCOVERY NETWORKS X4, BBC X2, NATIONAL GEOGRAPHIC CHANNEL

4 NOVEMBER

The Sky At Night

BBC One, 4 November, around midnight

After a run of over 55 years, Sir Patrick Moore is the longest-running presenter of the same television programme in the world. He did miss one show in 2004, but that's not a bad absence record for what was originally intended to be a run of three programmes. Along with Dr Chris Lintott, he'll be telling you what to watch out for in the winter skies, catching up with current space exploration and explaining the science behind what you can see.

FROM 5 NOV

Origins Of Us

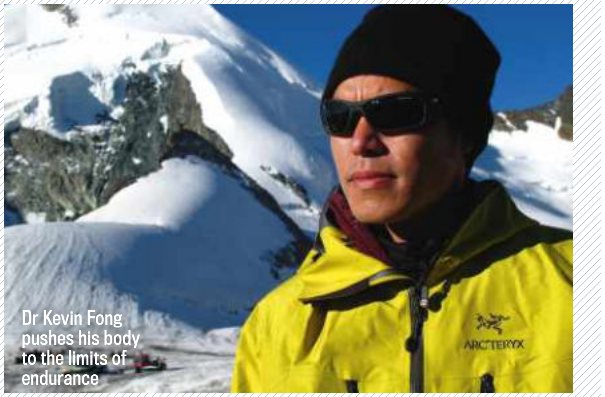
Eden, starts 5 November, 8pm

Anthropologist Dr Alice Roberts reveals the story of human evolution that's written in our own bodies. Initially aired on BBC Two, this three-part series covers six million years of adaptation from tree-dwelling ape to intelligent *Focus* reader. But though our complex brains and great taste in magazines give us a clear advantage as a species, they've come at a cost. Painful childbirth, backache and tricky wisdom teeth are all side effects of becoming human.

13 NOVEMBER

To Boldly Go

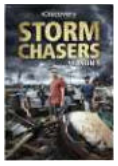
Eden, starts 13 November, 8pm



Dr Kevin Fong pushes his body to the limits of endurance

➔ WE'D ALL LIKE to go into space (wouldn't we?) but could our bodies take it? Dr Kevin Fong pushes his own to extremes in this BBC-made two-parter, as he finds out what it would take to go up into space and experience weightlessness in a vacuum, or down into the pressurised depths of the ocean. And though we have some remarkable biological tricks up our, um, arms, without technology we could never explore the remotest corners of our own planet, let alone reach for the stars.

DVD & BLU-RAY



Storm Chasers

15 DVD box set, Discovery Channel, £49.99

Fancy hours of the action-packed series that did for weather forecasting what *Deadliest Catch* did for fishing? It's hard to decide which is more gripping – the prospect of scientists being carried off by a tornado, or their obsession to see who can get closest to the eye of the storm.

Concorde: The Final Flight

DVD, Discovery Channel, £12.99

An affectionate look at Concorde's last passenger flight, from its rising like an ungainly swan – to tearful applause from its fans – to rolling to its last halt. Born in the technological and economic optimism of the 1960s, the real tragedy is that it has retired with no replacement in sight.

Through The Wormhole

2-Disc DVD and Blu-Ray, Discovery Channel, £29.99

The second season of the series matching Morgan Freeman's deep voice with equally deep questions. This time he asks whether time exists, what aliens look like and if we can travel faster than light. But those are mere canapés compared to the ones on living forever and life after death.

FROM 12 NOV

You Have Been Warned

Discovery, starts 12 November, 8pm

You can find pretty much anything on YouTube. But what you can't always find online is an explanation of the science, technology or maths behind the Roomba-surfing kittens you've just watched during work time (you think we don't know?). This series brings in assorted experts for a diagnosis of what makes these viral videos possible. From robot rock bands to human-powered flying machines, brace yourself for an onslaught of understanding.

FROM 13 NOV

Chasing UFOs

National Geographic, starts 13 November, 9pm

Are the citizens of California really being spied upon by aliens – and if so, does the former Governator know? Like a cross between *Stormchasers* and *The X-Files*, three intrepid investigators travel around the USA trying to identify unidentified flying objects. The first of the three episodes takes them to Roswell, New Mexico, where they use night vision gear at the site of the 1947 'alien spacecraft' crash. But in Texas, a pilot explains that strange phenomena may have rational explanations.

LISTEN

BBC RADIO PROGRAMMES

WITH TIMANDRA HARKNESS

FROM 28 OCT

The Living World

BBC Radio 4, starts 28 October, 6.35am

A return of the series that reports the latest news on wildlife, nature and the environment. Because it's a topical show we can't tell you what the presenters will be talking about, but in the past they've gone from Norfolk to Papua New Guinea in search of frogs, owls and pasque flowers, so we know they'll stop at nothing to keep you in touch with the natural world.

FROM 7 NOV

Frontiers

BBC Radio 4, starts 7 November, time TBC

A new seven-part season of the programme at the cutting edge of research. Hear about the newest ideas and investigations, and meet the scientists doing the work. Previous programmes have explored the creation of artificial blood, technology that mimics photosynthesis and the future of flight. They've also asked if we're approaching the end of Moore's Law, proof that the programme doesn't shy away from challenging subjects.

FROM 30 OCT

All In The Mind

BBC Radio 4, starts 30 October, time TBC

Psychologist Claudia Hammond returns with her weekly exploration of the human mind. From the experience of mental illness to the latest discoveries of neuroscience, the magazine format has room for both light and serious topics. Indeed, the ways we think and experience the world never cease to surprise.

FROM 19 NOV

The Infinite Monkey Cage

BBC Radio 4, starts 19 November, time TBC

Robin Ince and Brian Cox return with another series of the irreverent and playful hit show. No cage, no monkeys, only a little infinity, but a range of interesting and amusing guests and a quirky look at the latest topics in science. Look out, too, for a few live shows towards Christmas.

Ince and Cox: no monkeys were caged in the making of this programme

FROM 23 NOV

More Or Less

BBC Radio 4, starts 23 November, time TBC

The series that illuminates maths and statistics in the news is back. Tim Harford and his team can tell you if your distribution is normal, what the media mean by 'average' and what's the point of decimals. Previous topics have included league tables in Olympic medals and what percentage of teenagers get pregnant.

PHOTO: BBC

TOUCH

SMARTPHONE & TABLET APPS

WITH CHRISTOPHER PHIN

Inside Nature's Giants

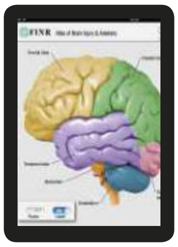
iPad, HarperCollins, £1.99

This app is the perfect way to explore the anatomy of some of the world's biggest creatures – even more so than the book and TV series on which it's based. Rotate one of a dozen colossal creatures such as an elephant and a whale in 3D, and swipe to reveal their skeleton and organs. While the annotations are sometimes hard to find and you might wish the information on each animal was a little more in-depth, the behind-the-scenes diaries, maps, and videos make it great to explore at your own pace.

Lunar Map HD

Android 1.5, Omega Centauri Software, 63p

Whether you're gazing at the Moon from the top of a hill with nothing but a Thermos to keep you company, or are comfortably tucked-up at home with a telescope, this is a comprehensive and detailed app for observers who want to visit the surface of Earth's satellite virtually. Choose a map type – including greyscale relief or topographic false colour – and either zoom and pan around to survey the annotated features, which you can tap for more information. Or search for something specific such as the Apollo 11 landing site.



FINR Brain Atlas

iOS, Florida Institute for Neurological Rehabilitation Inc, £1.49

If you wanted to explore the brain, you could book a dissection room, obtain a brain and retain the services of a specialist to help you distinguish one greyish mass from the next. Or you could just get this app. The information it presents about the different regions of the brain is pitched well for non-experts, while the rotatable, cut-away 3D models are both clear and surprisingly pretty. What's more, you can learn about the effects of common injuries, including what happens when a nail penetrates the skull.

CHRISTOPHER PHIN is the editor of *TAP!* magazine

PLAY

CONSOLE & COMPUTER GAMES

WITH NEON KELLY

Call Of Duty: Black Ops 2

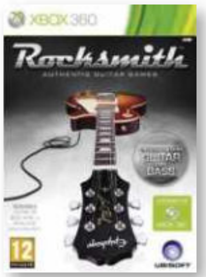
PS3, Xbox 360, PC; £39.99

WHERE THE FIRST *Black Ops* traded in Cold War nastiness, here the focus lies on stompy robots that have been hacked by the bad guys – thinly-veiled caricatures of the Occupy movement. While the plot might not make much sense – it rarely does in this franchise – most people will be picking this first-person shooter up for the finely tuned multiplayer mode. This allows three teams to play against each other at once, rather than the usual two. Love it or loathe it, don't expect to escape it...

Tokyo Jungle

PS3; £9.99

THE HUMAN RACE, you say? Long gone. And since civilisation has collapsed, pets are free to roam the wastes of post-apocalyptic Tokyo. That's the setup for this frankly bonkers downloadable game, combining exploration, survival and combat with animal husbandry. Pick a critter, from a fluffy chick to a crocodile, then explore the ruined city in search of food and a mate. *Tokyo Jungle* also features Pomeranian dogs in straw hats, which clearly makes it the most important release of 2012.



Rocksmith

PS3, Xbox 360; £59.99

ONCE WE WERE all *Guitar Heroes*, hacking away at our silly plastic instruments. Now, *Rocksmith* purports to offer the real deal. Grab an electric guitar, plug it into your console with the supplied cable, then let the game guide you on your journey to becoming the next Jimi Hendrix. Well, that's the theory. Rocksmith's presentation is a bit woolly, but the technology works if you're prepared to put the hours in. It has a cracking tracklist too, with tunes by Black Keys, White Stripes and the Rolling Stones.

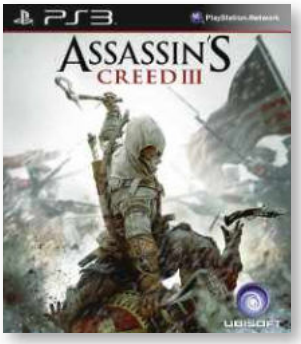
NEON KELLY IS DEPUTY EDITOR AT VIDEOGAMER.COM

These redcoats weren't quite as friendly as the ones at Butlins

EDITOR'S CHOICE

Assassin's Creed III

PS3, Xbox 360, PC; £39.99



AN ANNUAL FRANCHISE it may be, but *Assassin's Creed* provides arguably the smartest blockbusters in modern gaming. The core ingredients generally remain constant, providing a steady diet of subterfuge, parkour and acrobatic violence; yet this is also a series that dares to try new things, ferrying us to rich historical settings that largely go ignored by its peers.

Assassin's Creed III is actually the fifth *Creed* outing. The last three games traversed Renaissance-era Italy, but here we're transported to the birth of the USA in the middle of the 18th Century. Our new hero Connor Kenway is half English, half Native American, and is caught up in the conflict between the British Empire and the rebelling separatists. There's also a framing narrative in the present day involving the Knights Templar, but that's really just a sideshow: the main draw here is the chance to climb and free-run your way across the natural wilderness of the fledgling USA, dispatching unfortunate foes with bows, tomahawks and hidden blades.

Until now the *Assassin's Creed* games have largely revolved around city settings. Here you can visit colonial Boston and New York, but you'll also be traversing forests and snowy hilltops. In a touch that recalls *Red Dead Redemption*, you can practise your hunting skills on the local wolves and deer, or engage a grizzly bear in an ill-advised knife fight. There's also the chance to fight naval battles, taking to the seas as captain of your own ship.

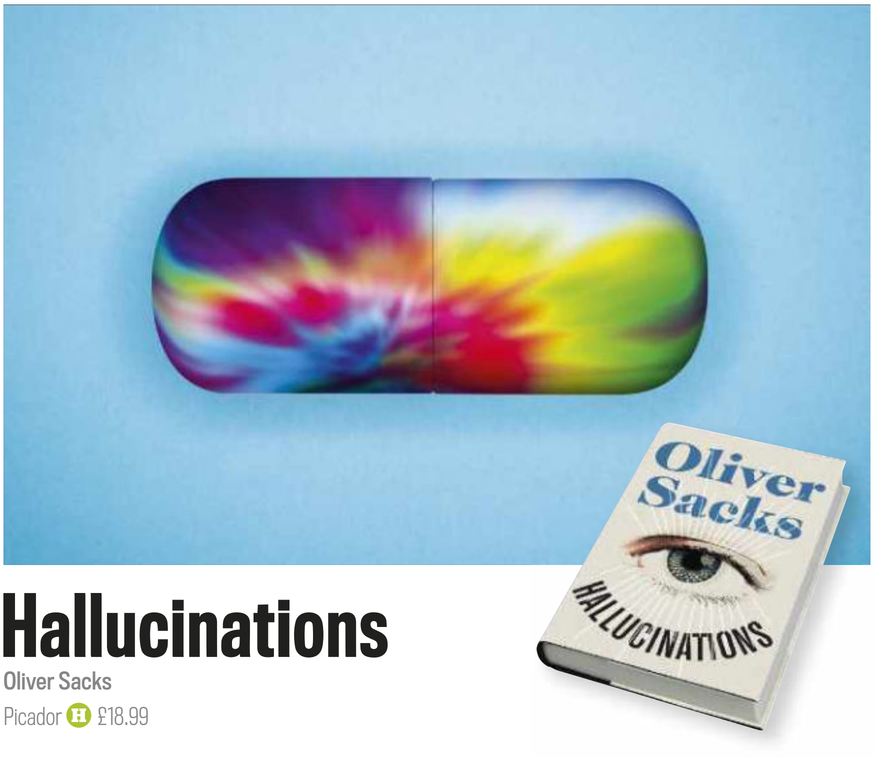
The game's plot spans 30 years of Connor's life, and features cameos by real-world historical figures Benjamin Franklin, George Washington and King George III. And as dense as this all sounds, the resulting experience is surprisingly accessible, with an emphasis on dynamic action and freedom for the player.

Put simply, this is an epic period drama with all the bark and bite of a *Bourne* film. What's not to like?

READ

THE LATEST SCIENCE BOOKS REVIEWED

P Paperback H Hardback



Hallucinations

Oliver Sacks

Picador H £18.99

PLUNDERING A TREASURE trove of clinical case histories that highlight the diversity of hallucinations, neurologist Oliver Sacks has woven together an entertaining narrative from the weird sensory experiences that only exist inside our heads.

In compelling accounts from young and old, we learn that hallucinations are surprisingly common. Yet, as Sacks explains with his trademark insight and compassion, those with neurological problems – as well as non-patients – rarely report hallucinatory experiences to their doctor for fear of being thought insane.

Most experiences don't have such dark implications, though. They may be vivid, shocking and absorbing – and can occasionally deceive people – but at the time those hallucinations occur, they're generally acknowledged as being illusions. Some people with visual problems see floating specks of light that turn into flocks of birds, swirling wheels and geometrical shapes in vibrant colours, whereas the experiences of patients with epilepsy or Parkinson's disease are more personal.

The book really comes alive when Sacks reveals his own dabbling with psychedelic drugs as a young doctor. This was the 1960s, in California, and a variety of drugs was readily available. On one occasion, after taking 20 tablets of Artane – a drug then used to treat Parkinson's – Sacks cooked breakfast for two friends who'd dropped by one Sunday morning, only to discover that they weren't there. This was shortly followed by the sounds of a helicopter landing to deliver his parents on a surprise visit. Another hallucination.

In this whirlwind tour of distorted perceptions, Sacks wonders whether hallucinations might have always played a role in our deepest expressions of art, folklore, literature and even religious experiences. He speculates on the machinations of how our brain produces vibrant misperceptions and delusions that not only give us a unique pathway to probe the brain itself, but also reveal that these neurological processes have probably always been central to human culture.

■■■■□

PROFESSOR ELAINE FOX is a cognitive psychologist and author of *Rainy Brain, Sunny Brain*

MEET THE AUTHOR

Oliver Sacks

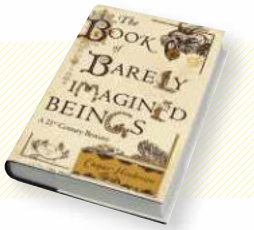
Why did you write this book?
I've written bits about hallucinations in earlier books, including *The Man Who Mistook His Wife For A Hat*, and it was time to bring it all together into a single book. Now we know something about the brain mechanisms involved – one can do functional brain imagery when particular hallucinations are going on.

What surprised you most?
I think bereavement hallucinations – after people lose a spouse, parent or child. There was a big study in Wales which showed that close to 50 per cent of bereft people had hallucinations and these were often welcomed and seen as part of the mourning process. When there's been 50 years of marriage, the other person is deep in one's brain, neurologically, and the brain responds to a hole or an absence by putting something in it.

Which part of the book was most challenging to write?
Probably the slightly scandalous chapter on my own drug-induced hallucinations, from which I learnt a lot about how the brain works: what I experienced often gave me insight into what my patients experienced. I didn't intend to write about it, but last year I was in hospital and a friend came by and I told him these stories. So that part of the chapter was evoked by a sympathetic listener and not written as such. I thought of omitting the whole thing but for better or worse, there it is, and I think lots of people will resonate with that.

MORE ON THE PODCAST
Listen to a longer interview with Oliver Sacks on the podcast at sciencefocus.com/podcasts

PHOTO: GETTY



The Book Of Barely Imagined Beings

A 21st Century Bestiary

Caspar Henderson

Granta Ⓗ £25

AS A ZOOLOGIST, I find all animals amazing, and most of them beautiful. But many others don't feel the same – indeed, people often equate the word 'animal' with 'mammal', not appreciating that creatures such as worms are animals too. *The Book Of Barely Imagined Beings* should help them view strange and wonderful animals with more delight.

Caspar Henderson takes particular species or groups of species, arranged from A to Z, to illuminate some of nature's most intriguing adaptations. He then uses them to explore evolutionary principles, philosophical ideas, human inventions, technologies and characteristics – all in a daisy-wheel of digressions and connections woven around the subject. From macaques to morality, salamanders to smallpox, sea urchins to symmetry, and worms to warfare, the author guides you along so smoothly that you won't notice how he got where he was going.

More than just a 'bestiary', Henderson's reflections about animals are always thoughtful, entertaining and often challenging.

■■■■□

PROFESSOR JENNY CLACK is a vertebrate palaeontologist at Cambridge University

The Where, The Why And The How

75 Artists Illustrate Wondrous Mysteries Of Science

Jenny Volvovski, Julia Rotman & Matt Lamothe

Chronicle Ⓗ £15.99

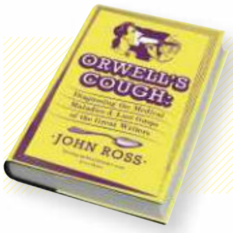
THE MARRIAGE OF science and art is not uncommon; Damien Hirst painted coloured spots for the Beagle 2 Mars lander, and Laurie Anderson joined NASA as its first artist in residence. Now this book's editors, from US design agency Also, have commissioned 75 artists to illustrate the answers to some of science's most fascinating questions, ranging from 'Why do placebos work?' to 'How flexible is the human brain?'

All the questions are mysteries to a lesser or greater extent, and this means that the illustrations necessarily need to be abstract. In fact, some do little more than nod at the answers provided by practising scientists. 'Where did life come from?', for instance, eschews RNA and amino acids in favour of Andy Warhol-like cans of 'primordial soup'.

The styles vary wildly, from collages to line drawings. Since none attempt a realistic representation, however, this book is more an attractive gift for a fellow science-lover than a reference tool.

■■■□□

GRAHAM SOUTHORN is the editor of *Focus* magazine



Orwell's Cough

Diagnosing The Last Gasps And Medical Maladies Of The Great Writers

John Ross

Oneworld Ⓗ £12.99

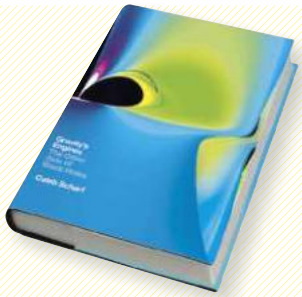
I PICKED UP Orwell's Cough with great enthusiasm, as it combines mysterious medical maladies with short biographies of great writers. John Ross, assistant professor of medicine at Harvard Medical School, starts well by making a compelling case that Shakespeare would have been at high risk of contracting syphilis. He certainly wrote about it a lot.

There were surprises too. I had no idea that the Elizabethan sweating therapy, which involved raising a patient's body temperature as high as they could take it, might actually have worked. The bacterium behind syphilis, *Treponema pallidum*, is sensitive to heat because it lacks a key protective feature.

Ross's attempts to make a link between syphilis, which Shakespeare may or may not have had, and his success as an author are far-fetched, but it's an enjoyable argument. After Shakespeare, however, the book becomes considerably less gripping. The next nine authors feel increasingly like being at a party with your favourite writers... only instead of giving you an insight into their thinking, all they talk about is their ailments.

■■■□□

DR MICHAEL MOSELY is a writer, doctor and BBC science presenter



Gravity's Engines

The Other Side Of Black Holes

Caleb Scharf

Allen Lane Ⓗ £20

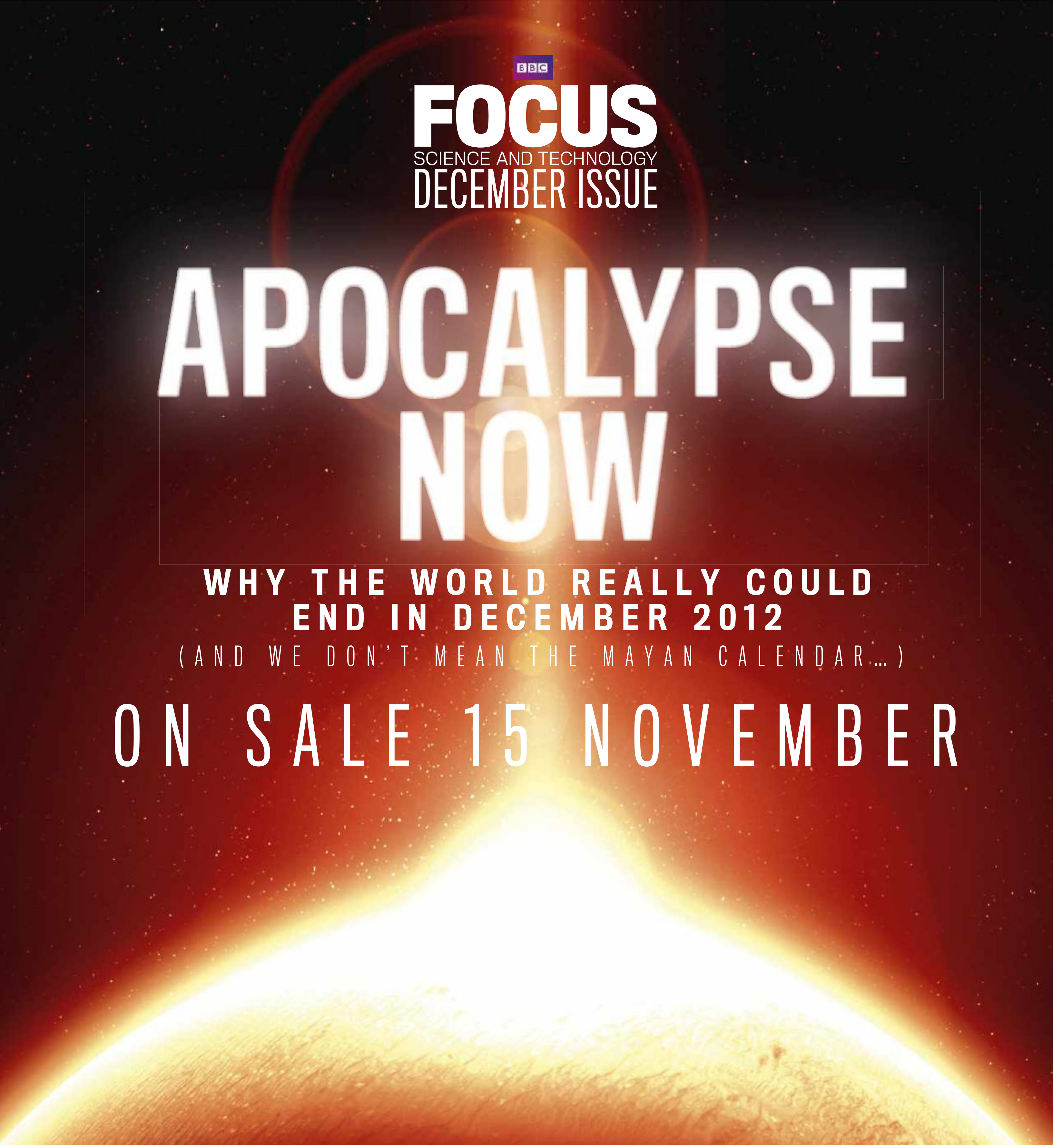
IF BLACK HOLES aren't 'petulant and fist-waving' then you're invited to consider the 'hungry beaks of nesting baby black holes'. Whatever the reason for this linguistic quirk in *Gravity's Engines*, there's little doubt that black holes are key characters in the story of our Universe's evolution.

Assuming little previous knowledge, it touches on just enough quantum mechanics and relativity to keep you turning the pages, a complicated tale in which you'll meet 'inverse Compton scattering' and 'bremsstrahlung radiation'. But the book's real strength is author Caleb Scharf's familiarity with the latest research. For example, he describes recent studies revealing that bubbles of hot gas inflate when the Galaxy's supermassive black hole consumes material. In doing so, he makes you understand why fuzzy pictures of bubbles of gas are quite so exciting.

While the closing chapter's attempt to link life to black holes is doomed to failure, this book should be on your shelf if you want to know why our Universe is the way it is.

■■■■□

DR CHRIS LINTOTT is an astrophysicist and co-presents *The Sky at Night* on BBC TV



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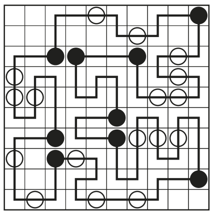

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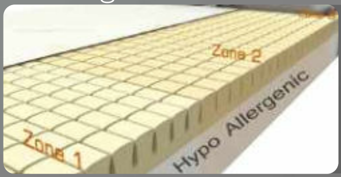

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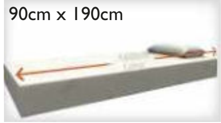

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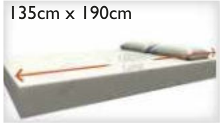

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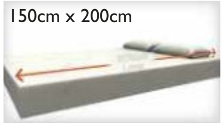

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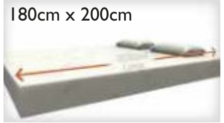

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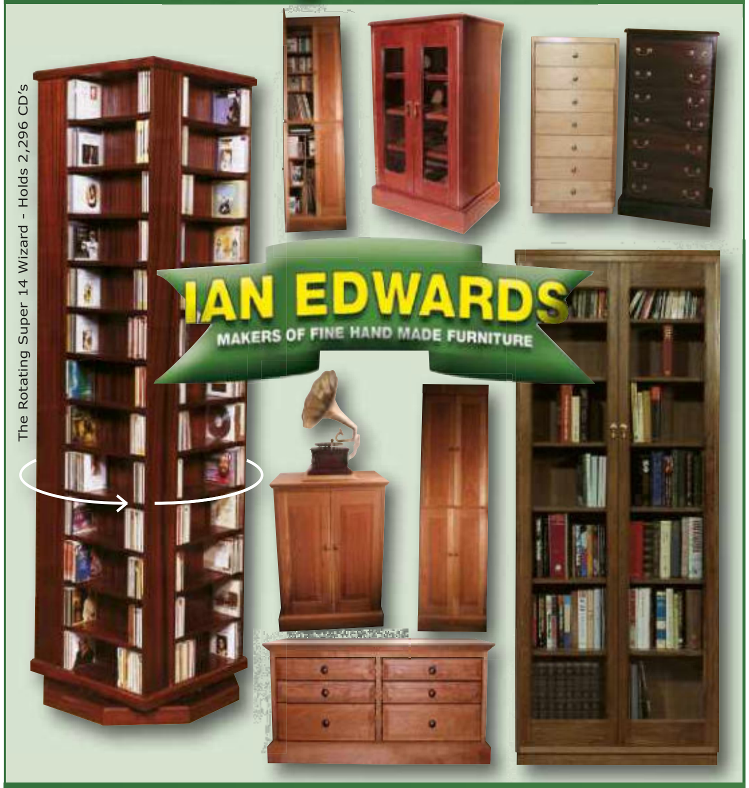

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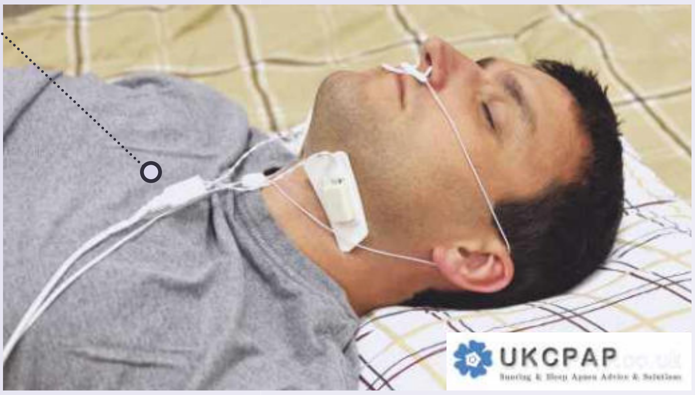

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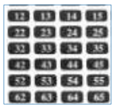

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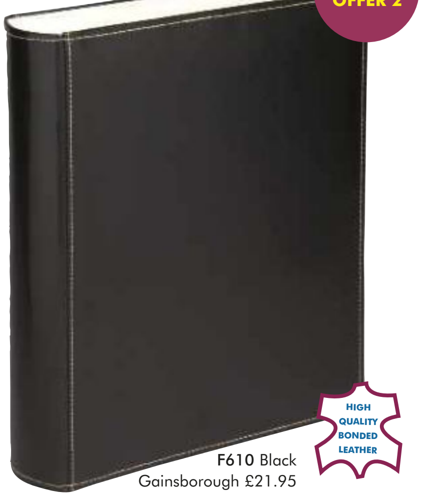

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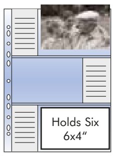

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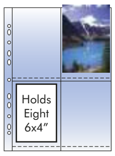

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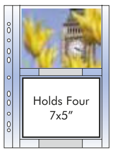

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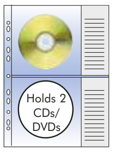

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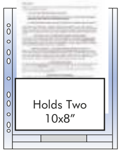

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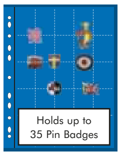
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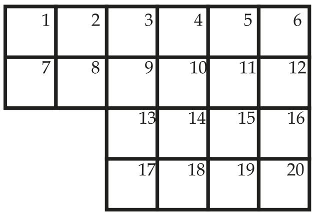

Cutting along the lines only, how can this piece of paper be cut into four identical shapes? Flipping and rotating the pieces is permitted.

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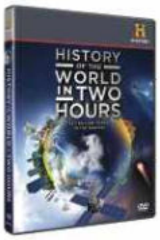


The first five correct entries win *A History Of The World In Two Hours* on DVD.

Post your entry, marked 'Prize Puzzle 248', to: *Focus*, PO Box 501, Leicester, LE94 0AA, to arrive by 5pm on 15 November 2012. We regret that we cannot accept email entries. See **sciencefocuscom/winners** for a list of previous solutions.

See bottom of p112 for terms and conditions. Congratulations to Steven Fukes (Norfolk), Stuart Milner (Leeds), Colin Long (Essex), Kathy Humphrey (Crewe) and Luke McLean (York) who all answered the August issue's Prize Puzzle correctly to each win a copy of *How To Remove A Brain.*

Q1

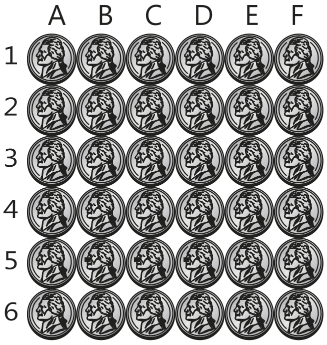
How is a piano worth two primates, ten lots of 2,240lb, 40 horses or 50 musical arrangements?

Q2

You need to photocopy some notes that are written on pages 14, 15, 27, 31, 32 and 34 of a pocket notebook. Without damaging the book, how much will that cost at 5p per photocopy?

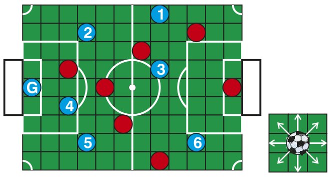
Q3

Remove six coins so that there is still an even number of coins in every row, column and main diagonal.



Q4

Starting at (G), how can the blues make six straight passes in any direction shown, avoid all the red players and score?



Q5

For each line, find the two letters that can be placed at the start and end to complete a word:

_ _ I M E N T _ _
_ _ T R O N O _ _
_ _ C A P T U _ _
_ _ E L A N D _ _
_ _ A R T A C _ _

Q6

If 'Sprain forearm' is TWIST WRIST, find rhyming couplets for the following: Not enough (3, 3); First woman's clothes? (4, 6); Cardiograph (5, 5); Win back admiration (6, 6); Impressionist's autobiography (7, 7); Hi! (8, 8); The White House (10, 9).

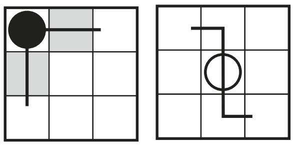
Q7

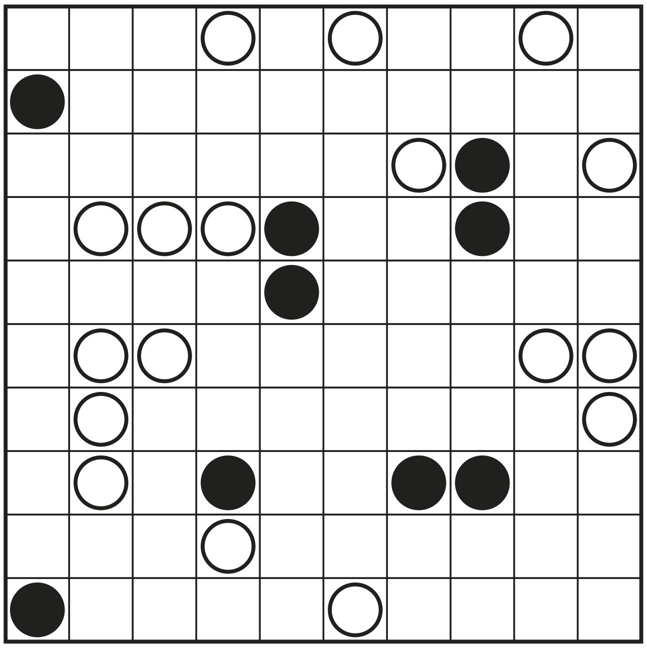
What type of land transport has a boat-related nickname but is also an old model of aircraft?

Q8

In this Masyu puzzle, draw a closed loop using horizontal and vertical lines that passes through the middle of all the black and white pearls shown. Where the loop enters a black pearl, the lines make a right angle, and also the two 'arms' must continue straight in both adjacent squares (shaded in the example diagram). Through white pearls, the line must keep going straight, and also make a 90-degree turn immediately before or after the white pearl (or possibly both). The loop has no dead ends, and never touches or crosses over itself. Not every square has to be used.

Example:





SOLUTIONS

Q1) 1 x £1,000 (grand) = 2 x £500 (monkey) = 10 x £100 (ton) = 40 x £25 (pony) = 50 x £20 (score).

Q2) 25p. Because it's a small notebook, pages 14/15 can fit on one copy. Page 31 is on the back of page 32, so the same trick doesn't work then.

Q3) Remove E4, F4, D5, E5, D6, F6. Other solutions exist.

Q4) G-2-6-5-3-1-4-goal.

Q5) ALIMENTAL, METRONOME, RECAPTURE, ICELANDIC, HEARTACHE.

Q6) Too few; Eve's leaves; Heart chart; Redeem esteem; Renoir's memoirs; Fleeting greeting; President's residence.

Q7) A camel (the 'Ship of the Desert'; Sopwith Camel).

Q8) See the 'Next month' page on p112 for the solution.

QUICK QUIZ

Test your knowledge of the planet Jupiter

Q1

Jupiter is primarily composed of which gas?
- a) Helium
- b) Methane
- c) Hydrogen

Q2

In what year did Pioneer 10 become the first spacecraft to visit the planet?
- a) 1973
- b) 1983
- c) 1993

Q3

Roughly how many Earths would fit inside Jupiter?
- a) 300
- b) 1,300
- c) 2,300

Q4

What is the name of Jupiter's largest moon?
- a) Io
- b) Ganymede
- c) Europa

Q5

Approximately how long is a Jovian day?
- a) 10 hours
- b) 20 hours
- c) 30 hours

Q6

Jupiter was named by which ancient people?
- a) Ancient Egyptians
- b) Ancient Greeks
- c) Romans

Q7

Which comet collided with the planet in 1994?
- a) Shoemaker-Levy 9
- b) Hale-Bopp
- c) Hartley 2

ANSWERS:

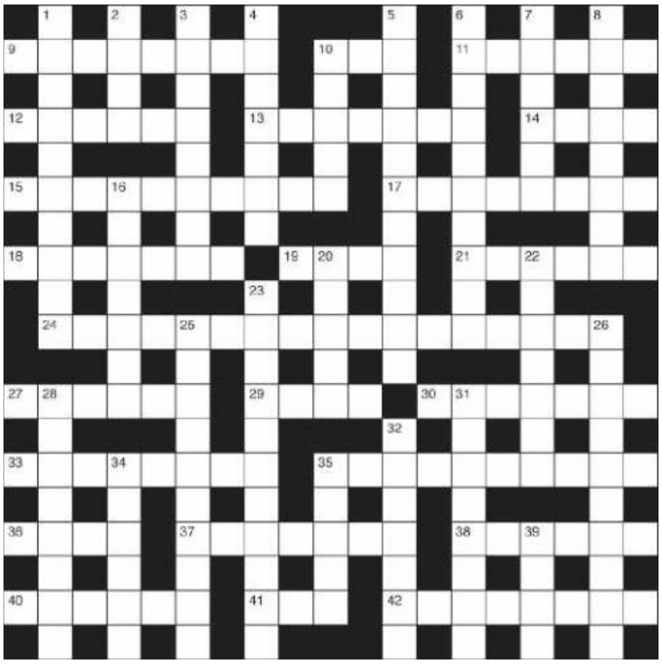
1c, 2a, 3b, 4b, 5a, 6c, 7a

YOU ARE...

0-3 A Little Red Spot
4-5 A Great Red Spot
6-7 A gas giant

FOCUS CROSSWORD No 144

EVERY MONTH, A NEW CHALLENGE SET BY AGENT STARLING



ACROSS

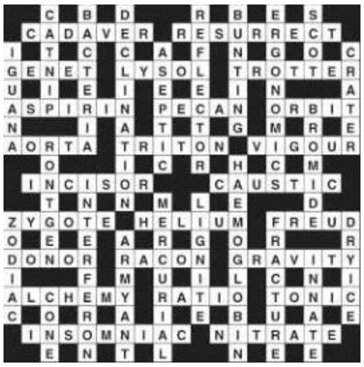
9 Mad hope is to get a line from an astronomer (8)
10 A sign from the galleon (3)
11 101 lice move round in chilly formation (6)
12 Right next to one singer from a Venetian island (6)
13 Gone round New Zealand to the East when solvent (7)
14 The weight of an Asia Minor city (4)
15 Settling gal into CIA is a very slow process (10)
17 City loss suffered due to contraction (8)
18 The loan was arranged in spirit (7)
19 When I get a lot of land (4)
21 Feline removed top part of flower (6)
24 Complaint concerning gamma rays (9,8)
27 Feeling of having seen this clue before (4,2)
29 Dynamism achieved with great speed (4)
30 Fight to have argument with weaverbird (7)
33 Eternal, only having three dimensions (8)
35 College gets mail on new maths expression (10)
36 Information on energy that's hereditary (4)
37 Ancient city has a point – aim to improve waste collection (7)
38 Free to work with union on German security (6)
40 Two-piece atoll (6)
41 A time of underachievement (3)
42 Some blonde in her element (8)

DOWN

1 I roll a cost out for frequency generator (10)
2 Ring friend to get a stone (4)
3 Cool road winding like a river (8)
4 Mathematician finds bile in new coordinate (7)
5 Same shoot is set up for maintenance of equilibrium (11)
6 Catfish, or something a bit bigger (5,5)
7 Painter of space probes (6)
8 Four-line composition about gas (8)
10 Range of products with new material (5)
16 Each lad wandered round part of Babylonia (7)
20 Coins fashioned using sound (5)
22 Article more about a proposition (7)
23 Student: 'I must organise daily acid test' (6,5)
25 Bath a quail uses has been adapted (5,5)
26 Spore producer organising main groups (10)
28 Record one medic's crazy rapid development (8)
31 Deity cares about the organ (8)
32 Sick puma suffered in Andean peak (7)
34 Lied about having the old visual impediment (6)
35 Father takes me back to British island (5)
39 Thwart with a sword (4)

SOLUTION TO CROSSWORD No 141

P Glendinning, John Hodgkinson, Martin Smith, Kathy Humphrey and Mr Pratt solved the issue 245 puzzle and each receive a copy of *How To Grow A Planet* on DVD.



WIN! A COPY OF *ATTENBOROUGH: SIXTY YEARS IN THE WILD*

The first five correct solutions drawn will each win a copy of *Attenborough: Sixty Years In The Wild* (BBC, £12.99). Entries must be received by 5pm on 15 November 2012. See below for more details.

YOUR DETAILS

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ADDRESS

POSTCODE TEL

EMAIL

Post entries to *Focus*, November 2012 Crossword, PO Box 501, Leicester, LE94 0AA or email a scan of the completed crossword or a list of answers to november2012@ focuscomps.co.uk by 5pm on 15 November 2012. Entrants must supply their name, address and phone number. By entering, participants agree to be bound by the terms & conditions, printed in full on page 112. Immediate Media, publisher of Focus, may contact you with details of our products and services or to undertake research. Please write 'Do Not Contact' on your email or postal entry if you do not want to receive such information by post or phone. Please write your email address on your postal entry if you would like to receive such information by email.

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How I Improved My Memory In One Evening

The Amazing Experience of Robert Heap

"Of *course* I place you! You're Bob Humphries of Birmingham."

"If I remember correctly — and I *do* remember correctly — John Kershaw, the supermarket man, introduced me to you at the dinner of the Bowls Club three years ago in October."

The assurance of this speaker — in the crowded corridor of the Hotel Piccadilly— compelled me to look at him.

"He is Dr. Bruno Furst, the most famous memory expert in the world"

"He is Dr. Bruno Furst, the most famous memory expert in the world," said my friend Keith Clark. "He will show you a lot more wonderful things than that before the evening is over."

And he did.

As we went into the banquet room the toast-master was introducing a long line of guests to Dr. Furst. I got in line, and when it came my turn, Dr. Furst asked, "What are your initials Mr. Heap, your occupation and telephone number?" Why he asked this, I learned later, when he picked out from the crowd the sixty people he had met two hours before and called each by name without a mistake. What's more, he named each person's occupation and telephone number.

"I can teach you the secret of a good memory in one evening"

When I met Dr. Furst he rather bowled me over by saying: "There is nothing miraculous about my remembering anything I want to remember, whether it be names, faces, figures, facts, or something I have read.

"*You can do this as easily as I do.* Anyone with an average mind can learn quickly to do exactly the same things."

"My own memory," continued Bruno Furst, "was originally very faulty. On meeting a man I would forget his name in thirty seconds, while now there are probably over ten thousand men and women in the world whose names I can recall instantly on meeting them."

"That is alright for you, Dr. Furst," I interrupted, "you have given years to it. But how about me?"

"Dramatic Improvement"

"I used to be laughed at in the office here about my poor memory and I must admit with a lot of truth. Since I started your Course my memory has improved out of all recognition!"

Mr. J.W. Sullivan, London S.W.2.

"Mr. Heap," he replied, "I can teach you the secret of a good memory in one evening. This is not a guess, because I have done it with thousands of pupils. In the first of twelve simple lessons which I have prepared for home study, I show you the basic principle of my whole system, and you will find it just like playing a fascinating game. I will prove it to you."

He didn't have to. His Course did; I got it the next day.

"Examination Success"

"Excellent examination results have been sound enough proof to carry on adopting your technique for the rest of our lives."

Mr. S.N. Caldwell, Huddersfield, Yorkshire.

When I tackled the first lesson, I was surprised to find I had learned — in about one hour — how to remember a list of one hundred words so that I could call them off forward and back without a single mistake.

That lesson *stuck*. So did the other eleven. Indeed, I was so impressed I introduced Dr. Furst's Course to this country.

Dr Bruno Furst's Course is fantastic! I can rely on my memory now. I can recall the name of anyone I have met before — and I keep getting better. I can remember any figures I wish. Telephone numbers come to mind instantly. What's more my concentration has improved.

Now I am sure of myself, confident, and relaxed when I get on my feet at the club, at a dinner, in a business meeting, or in any social gathering.

What's more, I have become more popular and influential.

My advice to you is don't wait another minute. Full details of Dr. Furst's amazing Course are available free on request. You could be astounded to learn what a wonderful memory you have got. Your dividends in both business and social advancement could be enormous.

ROBERT HEAP

"Best Investment"

"It is the best investment I have ever made. Why is it so cheap? The Course, apart from being so instructive, is easy to read and entertaining."

Mr. P.R. Jordan, (Ship's Officer)

FREE DETAILS

Full details of Dr. Furst's easy-to-follow method for developing a powerful memory are contained in a free information pack. To obtain your copy just telephone **0800 298 7070** free, send an e-mail (address below), post the coupon below - no stamp is needed - or visit our website at **www.youcanremember.com** and see how we can help you to improve your memory **TODAY.**

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INTO THE FUTURE

STEPHEN BAXTER

THE SUGGESTION THAT the OPERA physics experiment at Gran Sasso in Italy may have recorded subatomic particles travelling faster than light caused great excitement. It wasn't just would-be builders of faster-than-light starships like *Star Trek*'s Enterprise that started thinking big, but also dreamers who imagine building time machines like *Doctor Who*'s TARDIS. This is because every faster-than-light starship is also, potentially, a time machine.

The explanation for this is based on Einstein's Special Relativity, his science of motion and mechanics. It was Einstein who showed that the speed of light is (as far as we know) an absolute speed limit for the Universe. Furthermore, the rate at which time is measured depends on the motion of the person or object doing the measuring: this is Einstein's famous 'time dilation'. As a result, in Einstein's Universe there can be no universal clock, no universal time frame – and not even a universal agreement of the order in which events happen. Globally speaking there is no past and future. However, what keeps causality consistent – the 'event' of eating the omelette must follow the 'event' of breaking the eggs – is the speed of light. You could never send a message about the omelette you just ate back to the cook before he or she broke the eggs, without breaking the speed of light.

That was why the OPERA experiment was so exciting for would-be Time Lords. Breaking light-speed offered just a glint of hope that time travel might some day be possible.

It's tough being a T-rex: if it's not time-travelling hunters, it's an asteroid impact

But what if we were to achieve time travel some day? The idea is full of paradoxes, which trouble Doctor Who weekly. But the most fundamental one is this: if time travel is possible, where are all the time travellers? It is rather like the Fermi Paradox concerning the existence of aliens: if they exist, they should be here. Surely we ought to see evidence of any time travellers, especially at great events like the Battle of Hastings, or the crucifixion of Jesus.

> **"What if we were to achieve time travel some day? The idea is full of paradoxes, but the most fundamental one is this: where are all the time travellers?"**

Maybe the answer is that the time travellers are wary of altering history. A flash mob at Calvary, all waving futuristic camera phones, would certainly have changed the course of events on Good Friday. If they do show up, maybe they hide, carefully.

Or maybe the time travellers only visit events where their presence can make no difference. Ray Bradbury, who died recently, published a story called *A Sound Of Thunder* (1952), about time-travelling hunters who only kill dinosaurs doomed to die of natural causes. After the hunters shoot a T-rex, they see the event that would have killed it anyhow: "Overhead, a gigantic tree branch… crashed upon the dead beast with finality. 'There… right on time.'." A better bet for Bradbury's hunters might have been to show up on the very day of the asteroid impact believed to have killed off all the dinosaurs, especially if they travelled to the Yucatán peninsula, which would be vaporised by the impact, along with any trace of their presence. Of course, they would need to take care to get out of the way in good time.

As reported in *Focus* (June 2012), the OPERA neutrino speed measurement turned out to be an error in the instrumentation, and the prospect for time travel receded. But we have dreamed up other methods, such as using wormholes – errors in space and time connecting future to past. We can't yet say for certain that time travel really is impossible. And if by chance you *are* suddenly visited by a coach-load of time travellers who are careless of violating history, you should look to the skies to check for any looming big rocks… ■

STEPHEN BAXTER is a science fiction writer whose books include the *Destiny's Child* series and *The Science Of Avatar*

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